LAND

8

8.1 Introduction

The NT is internationally renowned for its vast and often spectacular scenery, much of which has outstanding wilderness values.[1] It is one of the few readily accessible and wild places on Earth.[2] The landscapes are not only integral to the Territory's identity, they are especially important to the cultural heritage of Aboriginal people, who retain a deep cultural and spiritual connection to land that has been fundamental to traditional society for millennia (issues specifically relating to Aboriginal people, their land, and their culture are addressed in Chapter 11). Not only are landscapes important to Territorians,[3] they are why most tourists choose to visit, making them fundamental to the Territory's tourism industry.[4] The Panel has heard from many Territorians who are passionate about protecting a lifestyle based on unspoiled vistas and preventing landscape industrialisation.[5]

The Panel has assessed the land-related risks associated with any onshore shale gas development in the NT, using the risk assessment framework detailed in Chapter 4. The Panel has assumed that the development of any onshore shale gas industry in the NT will only be acceptable if two land-related environmental values - terrestrial biodiversity and ecosystem health, and landscape amenity - are adequately protected. Development will be acceptable if the following environmental objectives are achieved:

- a low impact on the terrestrial biodiversity values of affected bioregions;[6]
- the maintenance of a regional scale of overall terrestrial ecosystem health, including the provision of ecosystem services;
- ensuring that any shale gas surface infrastructure does not become a highly visible feature of the landscape; and
- ensuring that the volume of heavy-vehicle traffic does not have an unacceptable impact on landscape amenity and place identity.[7]

In total, eight risks to terrestrial biodiversity and ecosystem health and landscape amenity have been considered.

Similar to Chapter 7, the Panel has also used the Beetaloo Sub-basin as a case study to focus attention on the land-related issues on the basis that the region is the most prospective shale gas area in the NT.

8.2 Land in the Northern Territory

8.2.1 Terrestrial ecosystems

The NT has a very strong north-south gradient in mean annual rainfall, which ranges from 2,000 mm on the Tiwi Islands off the northern coast to approximately 150 mm in the far south (**Figure 7.1**). Rainfall is a dominant driver of the distribution of plants and animals and also has a major effect on ecosystem function in the NT.[8] In particular, the summer monsoon dominates the rainfall of the northern and central regions (north of Tennant Creek), producing extensive herbaceous growth, which dries out and burns during the dry season.[9] This distinguishes the tropical savannah landscapes in the northern and central regions from the desert ecosystems to

1 Woinarski et al. 2007a; Alice Springs Town Council submission 235, p 2.
2 The Pew Charitable Trusts 2017, p 1.
3 Coomalie Community Government Council, submission 15 (**Coomalie Council submission 15**); Ms Yolande Doecke, submission 25 (**Y Doecke submission 25**); Ms Lisa Gray, submission 354 (**L Gray submission 354**); Mr Mark Swindles, submission 364 (**M Swindles submission 364**), p 1.
4 Arid Lands Environment Centre, submission 88 (**ALEC submission 88**), p 5; Mr Brian Baker, submission 207 (**B Baker submission 207**), p 9; Katherine Town Council submission 257, p 3; Mr Allan O'Keefe, Ms Marilyn O'Keefe and Ms Jasmin O'Keefe, submission 355 (**O'Keefe submission 355**), p 3; M Swindles submission 364; Ms Heather McIntyre, submission 366 (**H McIntyre submission 366**) , p 1; Somers submission 377.
5 For example: Mr Clinton Dennison, submission 5 (C Dennison submission 5); Ms Eleanor Wilson, submission 37 (**E Wilson submission 37**); Mr Tony Hayward Ryan, submission 41 (**T Ryan submission 41**); Ms Margaret Clinch, Planning Action Network, submission 51 (**PlAN submission 51**); Ms Sharyn Bury, submission 189 (**S Bury submission 189**); B Baker submission 207; Ms Jeananne Baker, submission 203 (**J Baker submission 203**).
6 Department of the Environment and Energy 2009.
7 Lee 2013.
8 Woinarski et al. 2007a.
9 Andersen et al. 2003.

the south. In the southern semi-arid and arid region, herbaceous production and subsequent fire are driven by decadal-scale periods of unusually high rainfall.[10] The desert-to-savannah transition occurs at an annual rainfall of about 500 mm/y and is the NT's primary biogeographic boundary, in terms of the composition of plant and animal species.[11] The next most important boundary is between the semi-arid savannahs of the central region and the high-rainfall savannahs of the northern region at around the latitude of Katherine.[12]

8.2.2 Terrestrial biodiversity

The NT has exceptional terrestrial biodiversity values, featuring a wide range of habitats and high levels of species diversity and endemism.[13] Almost all of the NT is covered by natural vegetation due to very limited agricultural development. There is extensive pastoralism[14], but this has involved little tree clearing, and therefore, terrestrial ecosystems are in generally good condition, with much of the NT's biodiversity largely intact.[15] A major exception is the small mammal fauna, which has suffered severe depredations by feral animals, especially foxes and cats. Many of the small mammal species from arid regions are now extinct,[16] and species from the northern higher rainfall zone have undergone recent population crashes due, in part, to predation by cats and exacerbated by the removal of shelter due to fire and high levels of grazing.[17]

In total, the NT has 90 plant species recognised as "*threatened*" under Commonwealth or Territory legislation.[18] It has 126 terrestrial animal species recognised as *"threatened"*, comprising 48 mammals, 31 birds, 12 reptiles, one frog and 34 invertebrates (30 land snails, three butterflies and a moth).[19]

The expanse of the relatively intact savannah landscape of northern Australia, including much of the central and northern part of the NT, represents one of the very few large natural areas remaining on Earth,[20] and the larger scale biodiversity value is due to the continuing connectivity of landscape-wide ecological processes. The largest expanses of tropical savannah woodland in good condition occur in Australia, giving Australia's tropical savannahs global conservation significance.[21]

The Australian monsoon tropics have a vastly under-described fauna, with fine-scale endemism equivalent to that in the rainforests of eastern Australia. They represent a major component of Australia's evolutionary heritage.[22] In a study of the Mitchell grass plains of northern Australia, a feature of the Barkly Tablelands and southern parts of the Beetaloo Sub-basin in the NT, Fisher[23] noted that these grasslands were poorly represented in the national conservation reserve system and had been inadequately studied ecologically, but that they nevertheless formed a distinct zone of regionalisation for vascular plants, all invertebrate taxa, and some vertebrate groups. The understanding of the broader biodiversity values of the arid zone landscapes further south is even more limited, although the existence of an unusually high diversity of some groups, such as lizards and ants, is well established.[24]

DENR has provided the Panel with information on terrestrial biodiversity in the Beetaloo and Southern Georgina Sub-basins.[25] It shows that the Beetaloo Sub-basin has been moderately well

10 Nano et al. 2012.
11 Andersen et al. 2015.
12 Andersen et al. 2015.
13 Woinarski et al. 2007a.
14 Mr Daniel Tapp, submission 11 (**D Tapp submission 11**); Mr Rohan Sullivan, submission 18 (**R Sullivan submission 18**); North Star Pastoral, submission 26 (**North Star submission 26**); Mr Tom Stockwell and Ms Tracey Hayes, Northern Territory Cattlemen's Association, submission 32 (**NTCA submission 32**); Mr Rod Dunbar, submission 75 (**R Dunbar submission 75**); Barkly Landcare submission 241.
15 Woinarski et al. 2007a.
16 Woinarski et al. 2007b.
17 Woinarski et al. 2011; Davies et al. 2017.
18 NT Government, Threatened plants list.
19 NT Government, Threatened animals list.
20 Woinarski et al. 2007a, pp 1, 45, 47, 50.
21 Woinarski et al. 2007a, p 1.
22 Moritz et al. 2013.
23 Fisher 2001.
24 Morton and James 1988.
25 DENR 2016.

sampled for plants (1,341 known species), but only sporadically sampled for vertebrates (437 known native species), with sampling concentrated around main roads. The vertebrate fauna includes 17 *"threatened"* species. There have been no systematic invertebrate surveys in this region.

The flora and fauna of the Southern Georgina Sub-basin is even less well known, but includes at least 825 native plant and 293 native vertebrate species, 10 of which are listed as *"threatened"*. It is the Panel's opinion that such limited information on the biodiversity assets of these prospective shale gas development regions represents a severe knowledge gap for assessing the risks of any such developments beyond the exploration phase.[26]

8.2.3 Bioregions

Bioregions are relatively large areas of land areas recognised has having a distinct climate, landforms, native vegetation and biota. [27] The Interim Biogeographic Regionalisation for Australia (**IBRA**) divides the country into 89 bioregions,[28] 24 (or parts thereof) occur in the NT (**Figure 8.1**). IBRA has been established to support the systematic development of a comprehensive, adequate and representative national reserve system. It is a tool supported by all levels of government to assist with identifying land for conservation as well as monitoring and evaluating natural resource management initiatives.[29] The Panel considers it appropriate to examine the development of any onshore unconventional shale gas reserves in the context of affected IBRA bioregions, and their associated values. IBRA bioregions were taken into account by Santos in the 2016 Southern Amadeus Seismic Program.[30]

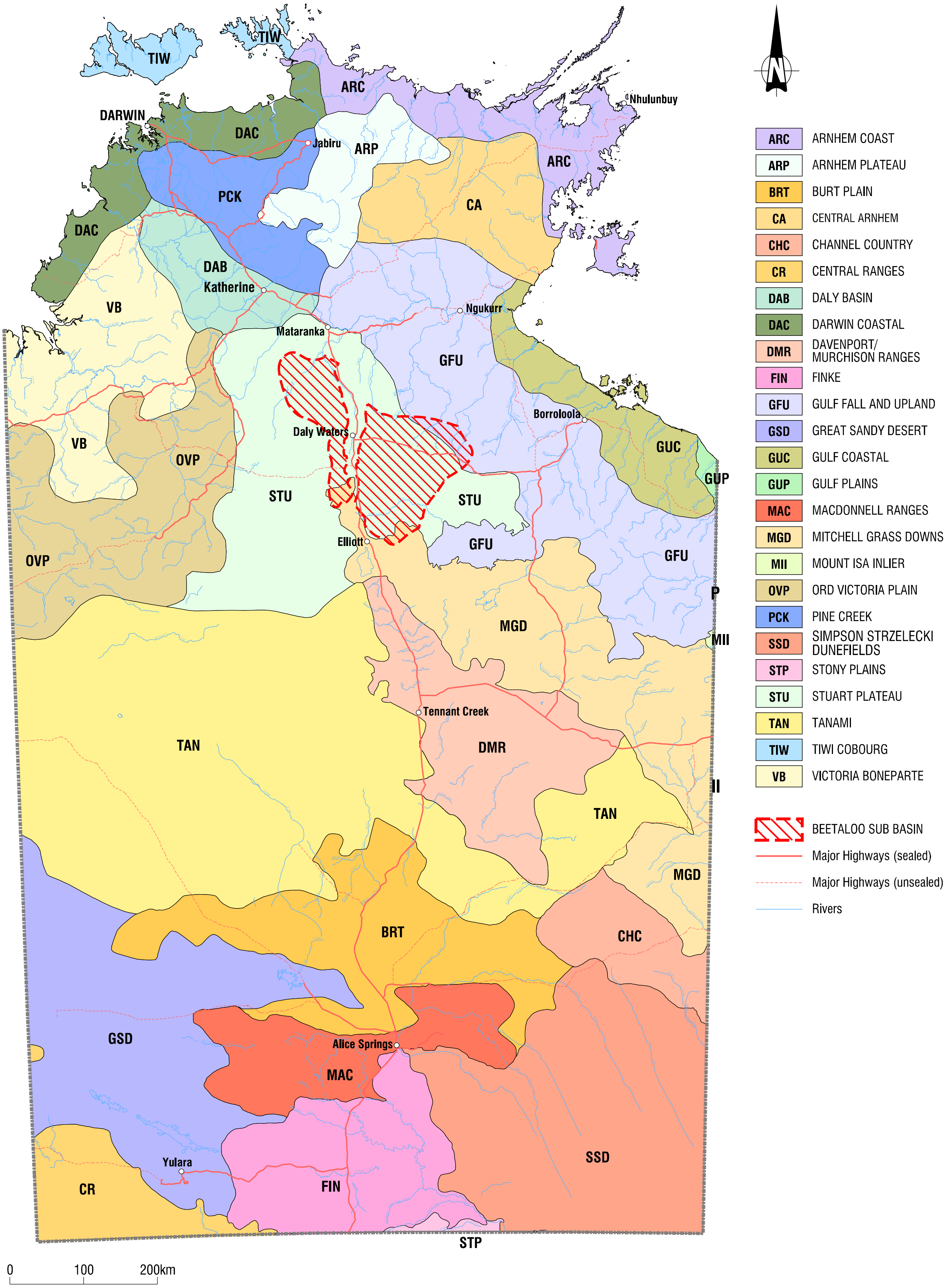
The Beetaloo Sub-basin (26,200 km^2) is located primarily within the Sturt Plateau Bioregion (an area of over 98,000 km^2), but extends into the Mitchell Grass Downs and Gulf Fall and Uplands at its southern and eastern extents. Gently undulating plains on lateritised Cretaceous sandstones, with predominantly neutral sandy red and yellow soils, dominate the Sturt Plateau Bioregion (**Figure 8.1**).[31] Elevation ranges from 100 to 300 m above sea level.[32] The most extensive vegetation is eucalypt woodland with tussock grass or Triodia understorey, but there are also large areas of lancewood (*Acacia shirleyi*) thickets, and bullwaddy (*Macropteranthes kekwickii*) woodlands, and small areas of Melaleuca woodland over grassland.[33]

The Sturt Plateau, Mitchell Grass Downs and Gulf Fall and Uplands are all considered to be under-represented in the National Reserve System, with less than 1% of each protected in the NT.[34] For this reason, consideration must be given to protecting areas of high conservation significance that are not part of the reserve network.

Indicative dominant vegetation at Amungee NW-1 and Beetaloo W-1 wells in the Beetaloo Sub-basin. Source: Origin.[35]

26 Environmental Defenders Office (NT) Inc, submission 213 (**EDO submission 213**), p 10.
27 Department of the Environment and Energy 2009.
28 ILC 2013.
29 ILC 2013.
30 DPIR submission 226, pp 8, 41.
31 Baker et al. 2005.
32 Baker et al. 2005.
33 Origin submission 153, p 92.
34 Thackway and Cresswell 1995.
35 Origin submission 153, p 93.

Figure 8.1: Interim Biogeographic Regionalisation for the NT. Source: Department of the Environment and Energy.[36]



36 Department of the Environment and Energy 2009.

8.2.4 Land management

8.2.4.1 Legislation

The NT has a suite of legislation that is relevant to the development of an onshore shale gas industry (see also Chapter 14). Relevantly, this legislation:

- determines where development may occur, for example, development cannot occur on reserved blocks (see Chapter 14);
- establishes a system of national parks, conservation reserves, heritage conservation areas and MNES that inform development proposals;
- establishes an environmental assessment framework; and
- provides for the conservation and management of land, including weed, fire and feral animal control.

Land management and the mitigation of potential environmental impacts in the NT are governed by the legislation below:

- **Petroleum Act** and **Petroleum Environment Regulations:** these laws ensure that onshore unconventional gas activities are carried out in a manner consistent with the principles of ESD and that environmental impacts and risks associated with the activities are reduced to a level that is ALARP.[37] To achieve this aim, interest holders must have an approved EMP in place before a regulated activity can be undertaken. Once approved, the EMP functions as an implementation and management tool for field operations and as a statutory compliance checklist for use by the regulator (see Chapter 14);[38]
- ***Environmental Assessment Act 1982*** **(NT) (EAA):** proposed developments that could potentially have a significant environmental impact must be referred to the NT Environment Protection Authority (**EPA**) for assessment under this Act. To date, no exploration projects, including seismic survey and limited shale gas exploration drilling (including hydraulic fracturing), have been required to be referred for assessment under the EAA.[39] However, such a referral is likely to be required for any proposal involving shale gas production;
- **EPBC Act:** the EPBC Act provides a legal framework to protect and manage MNES, including nationally and internationally important flora, fauna, ecological communities, and heritage places. If an action might have a significant impact on a MNES, the action may require assessment under the EPBC Act. The NT has a 'bilateral agreement' with the Commonwealth under the EPBC Act, which allows the EPA to undertake the assessment, but any decision regarding the approval of the action or any conditions on that approval remains the decision of the Australian Government Minister for the Environment.[40]

  Mining or the construction of new roads may require approval under the EPBC Act where they occur in areas where MNES are present. The Arnhem Plateau Sandstone Shrubland Complex is the only threatened ecological community listed as a MNES in the NT.[41] There are two Ramsar wetland sites in the NT: the Cobourg Peninsula and Kakadu National Park. These sites do not, however, occur on shale gas source rocks. The EPBC Act also covers unique assemblages of plants and animals associated with Great Artesian Basin springs, which can occur in the south east of the NT, but have not been specifically identified in that part of the Basin.

  The EPBC Act also provides for the identification and listing of key threatening processes (**KTP**), which are processes that may threaten the survival, abundance, or evolutionary development of a native species or ecological community. [42] If a KTP is listed, a threat abatement plan (**TAP**) can be developed in response. TAPs establish a national framework to guide and coordinate Australia's response to KTPs listed under the EPBC Act. TAPs identify the research and management priorities necessary to assist the long-term survival of native species and ecological communities affected by key threatening processes. In 2009, the Australian Government listed as a KTP under the EPBC Act: *"ecosystem degradation, habitat loss and species decline due to invasion of northern Australia by*

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37 DPIR submission 226, pp 8, 41.
38 DPIR submission 226, p 10.
39 DPIR submission 226, p 9.
40 Commonwealth of Australia and NT Government 2014.
41 SEWPaC 2012a.
42 EPBC Act, s 267.

introduced gamba grass (Andropogon gayanus), para grass (Urochloa mutica), olive hymenachne (Hymenachne amplexicaulis), mission grass (Pennisetum polystachion) and annual mission grass (Pennisetum pedicellatum)."

This initiated the development of the *"threat abatement plan to reduce the impacts on northern Australia's biodiversity by the five listed grasses"* (**Grasses TAP**).[43] The Grasses TAP identifies these grass species as having the ability to change native species composition through competition and by promoting intense, late season fire through increased fuel loads;

- ***Territory Parks and Wildlife Conservation Act 1976* (NT) (TPWC Act):** this Act enables the establishment of parks and reserves in the NT. Once established, a park or reserve affords legal protection to wildlife contained within it and protects the land from certain activities (unless undertaken in accordance with a management plan). Examples of activities that can only be done in accordance with the management plan are excavation, building construction and timber felling. Notably, the status of a park or reserve does not protect land from onshore shale gas exploration,[44] however, some parks in the NT, including Elsey National Park and Watarrka are recognised as Petroleum Reserved Blocks under the Petroleum Act, which means that no drilling or exploration for petroleum resources can occur in them (refer to **Figure 14.7** of this Report). The location of parks and reserves relative to prospective source rocks is discussed in Section 8.2.4.2.

  In accordance with the TPWC Act, the Minister must identify the conservation status of each species of wildlife in the NT, including threatened wildlife. Wildlife must subsequently be managed in a manner that accords with their classification. In the case of threatened wildlife, management must maintain or increase their population and the extent of their distribution in the Territory. Conversely, feral animals, declared under s 47 of the Act, must be managed in a way that reduces their population and/or extent and controls any detrimental effect they have on wildlife and the land.[45] Management programs for the control and management of feral animals can be established under the Act;
- ***Heritage Act 2011* (NT) (Heritage Act):** the object of this Act is to provide for the conservation of the Territory's cultural and natural heritage; [46]
- ***Weeds Management Act 2001* (NT) (Weeds Act):** the purpose of the Weeds Act is to prevent the spread of weeds in, into, and out of, the Territory, and to ensure that the management of weeds is an integral component of land management. The NT has 139 declared weed species,[47] many of which are highly invasive and have already had a substantial impact on conservation and agricultural production. There are three classes of declared weed species, each requiring different management measures that generally correspond to the relative risk of a weed having significant negative economic, environmental and/or social and cultural impacts (weed risk), and the comparative ease or feasibility of being able to control the weed species in a given weed management region (feasibility of control).

  Weed Management Plans are statutory documents that set out the legal obligations of landowners and occupiers to manage some of the highest risk and established declared weed species. There are currently 10 plans in force: for bellyache bush, cabomba, chinee apple, gamba grass, mesquite, mimosa, neem, prickly acacia, grader grass and athel pine.[48]
- ***Bushfires Management Act 2016* (NT) (Bushfire Management Act):** this Act provides the framework for managing bushfire in areas outside urban areas and major towns in the NT. The Act focusses on fire management rather than fire exclusion, in part by establishing a framework for bushfire management based upon bushfire risk and the preparation of regional bushfire management plans in consultation with landowners and other stakeholders. There is further discussion on fire in Section 8.4.3.

43 SEWPaC 2012b.
44 *Territory Parks and Wildlife Conservation Act* (NT), s 17.
45 *Territory Parks and Wildlife Conservation Act* (NT), s 31.
46 Heritage Act, s 3(2).
47 NT Government, Declared weeds.
48 NT Government, Statutory Weed Management Plans.

8.2.4.2 Parks, reserves, areas of conservation significance and Indigenous protected areas

The Parks and Wildlife Commission NT manages 87 parks and reserves established in accordance with the Territory Parks and Wildlife Conservation Act.[49] There are also two federally managed parks in the NT, Uluru-Kata Tjuta and Kakadu National Parks, which are recognised under the EPBC Act. National Parks and other formal reserves account for approximately 9% of the NT, but these areas have not been selected on the basis of a systematic assessment of NT's biodiversity values, and are not wholly representative of the NT's biodiversity.[50] For example, the Mitchell grass plains that are a feature of the Barkly Tablelands and the southern parts of the Beetaloo Sub-basin, form a distinct zone of regionalisation for vascular plants, all invertebrate taxa and some vertebrate groups, and yet are poorly represented in reserves.[51] There is increasing recognition within the community that the current reserve system does not adequately represent all of the NT's biodiversity.[52]

In 2009 the Government identified 67 sites of significance for biodiversity conservation in the NT. Twenty-five of these sites are considered to be of national significance and 42 of NT significance.[53] Conservation significance for biodiversity was determined using a broad range of determinants, including wetland values, importance to migratory species, habitat for threatened species, endemism and other internationally accepted criteria.[54]

The NT also includes several Indigenous Protected Areas (**IPAs**), which are voluntarily dedicated by Aboriginal land and sea owners for biodiversity conservation, and are funded by the Commonwealth as an important part of the National Reserve System. One IPA, Angus Downs, adjoins the southern extent of the prospective shale gas areas in the NT.[55]

A number of reserves and conservation sites that currently overlap with, or are in close proximity to prospective shale areas, are shown in **Figure 8.3** (Beetaloo Sub-basin) and **Figure 8.4** (Central Australia).

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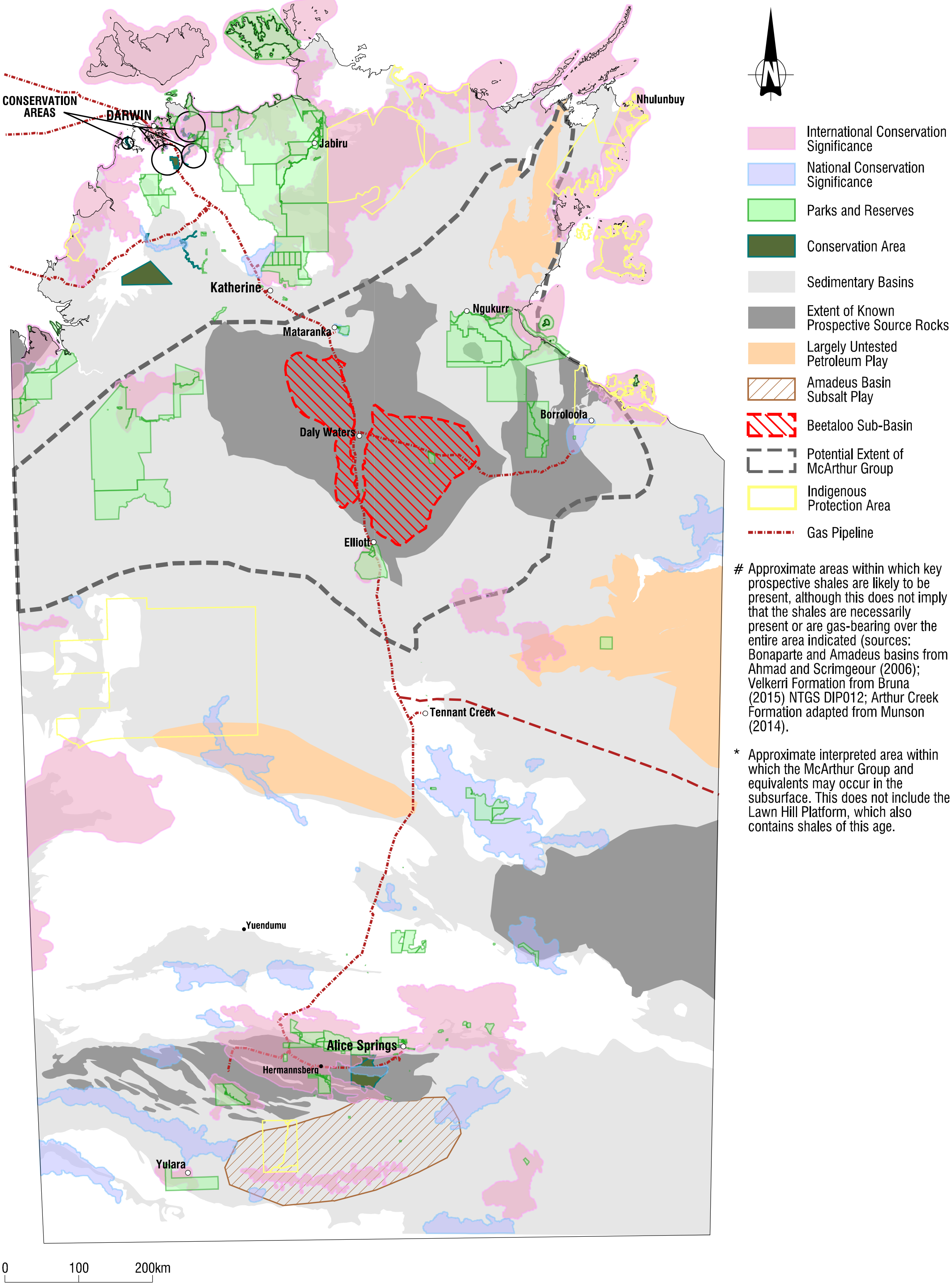
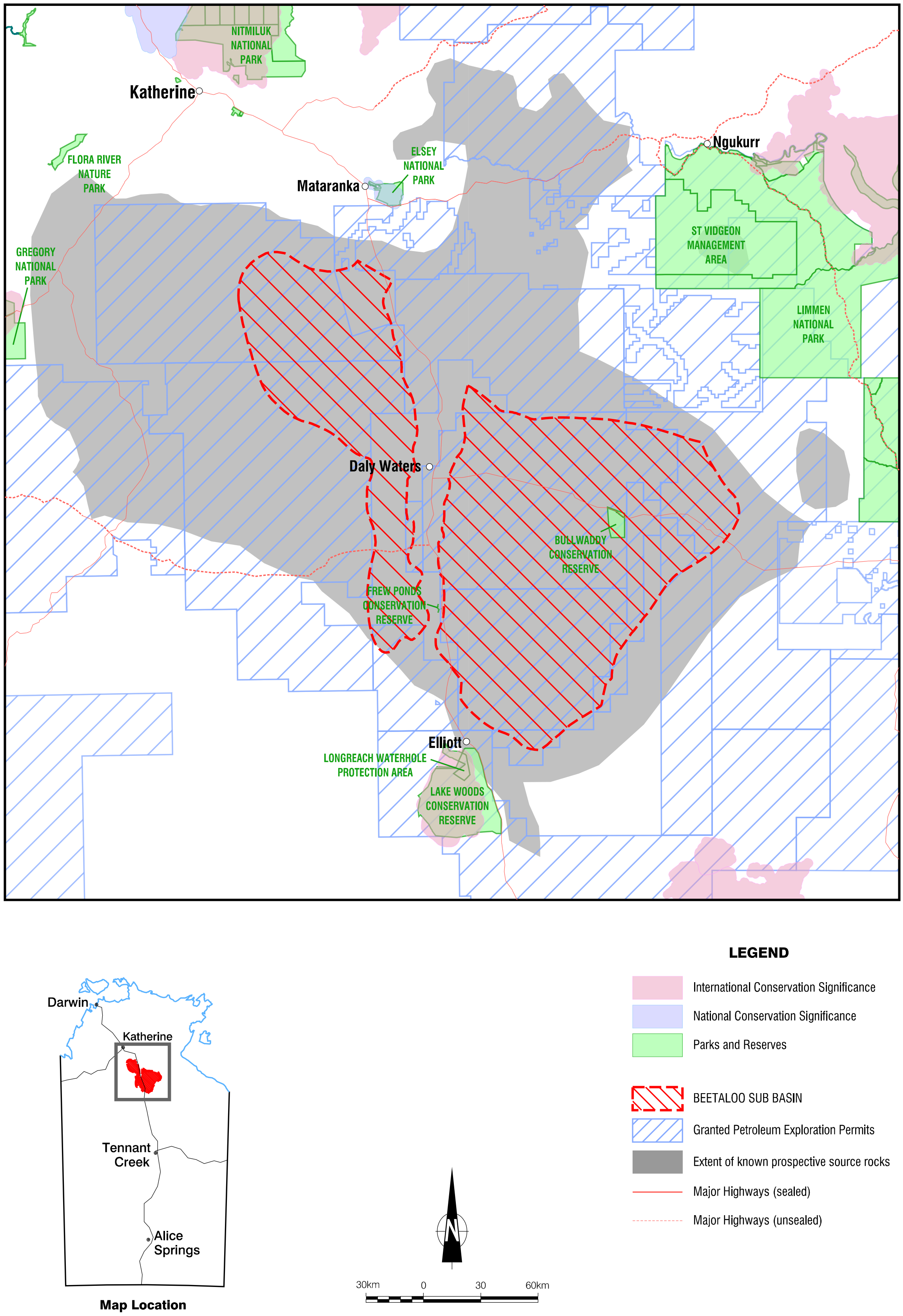
49 *Territory Parks and Wildlife Conservation Act* (NT), s 12.
50 Ward and Harrison 2009, p 1.
51 Fisher 2001.
52 Ward and Harrison 2009, p 1.
53 Ward and Harrison 2009, p 6.
54 Ward and Harrison 2009, p 2.
55 Australian Government, List of Indigenous Protected Areas.

Figure 8.2: Locations of all national parks, conservation reserves and sites of conservation significance[56] in relation to shale-gas regions in the NT. Source: Northern Territory Government.



56 Harrison et al. 2009.

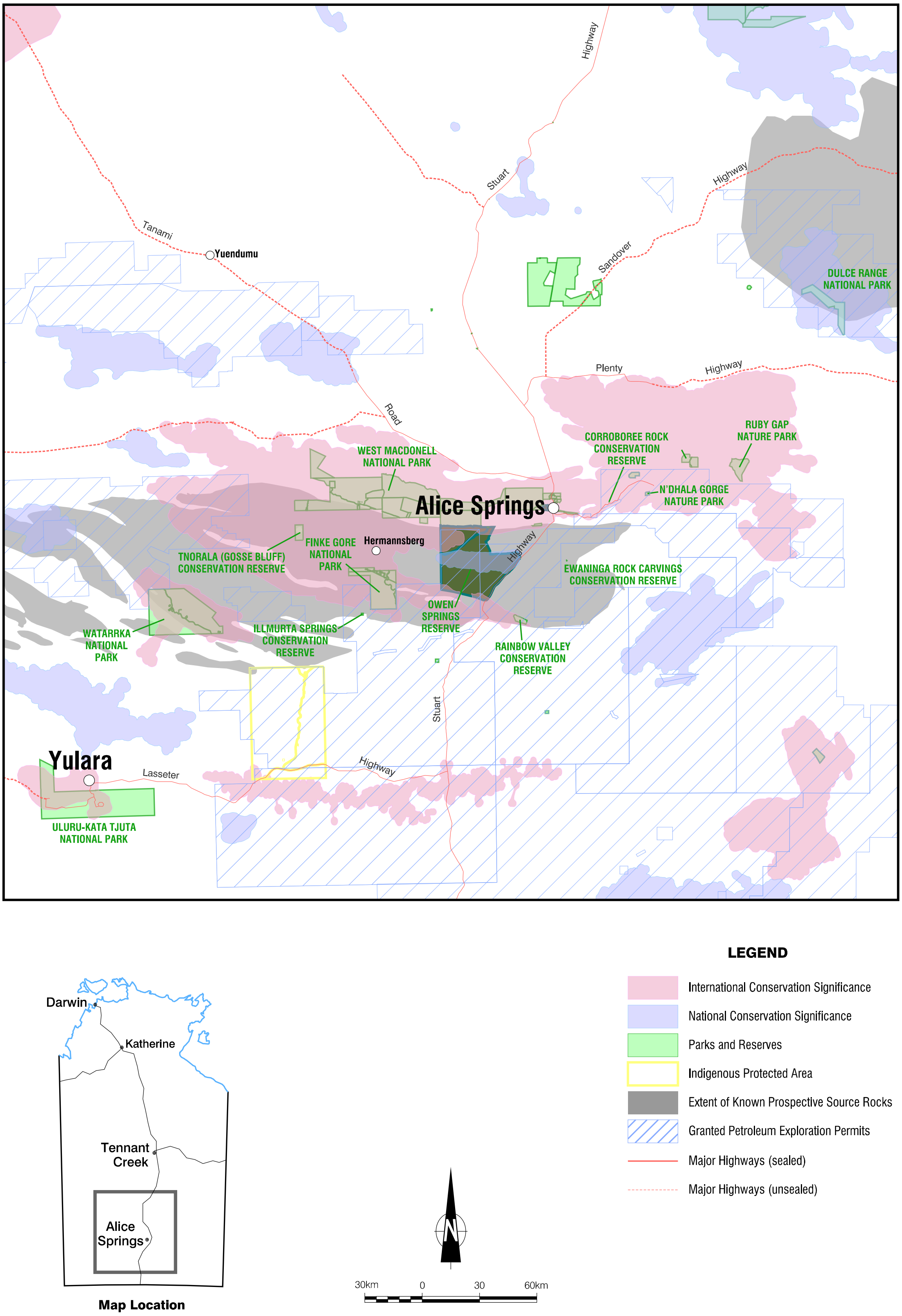
Figure 8.3: Locations of all national parks, conservation reserves and sites of conservation significance[57] in relation to shale gas regions in the vicinity of the Beetaloo Sub-basin. Source: Northern Territory Government.



57 Harrison et al. 2009.

NORTHERN TERRITORY GOVERNMENT

Figure 8.4: Locations of all national parks, conservation reserves and sites of conservation significance[58] in relation to shale gas regions in the southern NT. Source: Northern Territory Government.



58 Harrison et al. 2009.

The following conservation reserves occur in, or close to, the Beetaloo Sub-basin:

- **Bullwaddy Conservation Reserve** (Portion 5680): located approximately 100 km east of Daly Waters along the Carpentaria Highway. The 115 km^2 reserve was relinquished from Amungee Mungee Station in May 1999 and is now freehold land held by the NT. The reserve represents the only declared conservation area within the Sturt Plateau region of the lancewood and bullwaddy vegetation types. The Reserve's management plan acknowledges that the conservation of Acacia woodlands is severely under represented in protected areas, with less than 1% conserved in the Territory and 3% nationally;
- **Lake Woods:** this is an internationally significant semi-permanent wetland, which adjoins the southern tip of the Beetaloo Sub-basin. Its eastern edge runs parallel to the extent of known prospective source rocks in the area. Lake Woods is one of the largest freshwater lakes in Australia, and generally has an area of approximately 350 km^2. During major rainfall and flooding events it can extend to 1,000 km^2, when it can physically join the lower reaches of Newcastle Creek (see **Figure 7.8**). Lake Woods is identified as a site of significant refugia for biological diversity in arid and semi-arid Australia due to its importance as a breeding and migratory stopover location for waterfowl. The reserve is popular for conservation and recreation purposes;[59] and
- **Historical Frew Ponds Overland Telegraph Line Memorial Reserve:** established under the former *Heritage Conservation Act* (NT) in 1962, this is a section of the original Overland Telegraph Line. The reserve is located on NT Portion 500 within Hayfield Station.

Pelicans at Lake Woods. Source: Matt Bolam.

59 Harrison et al. 2009.

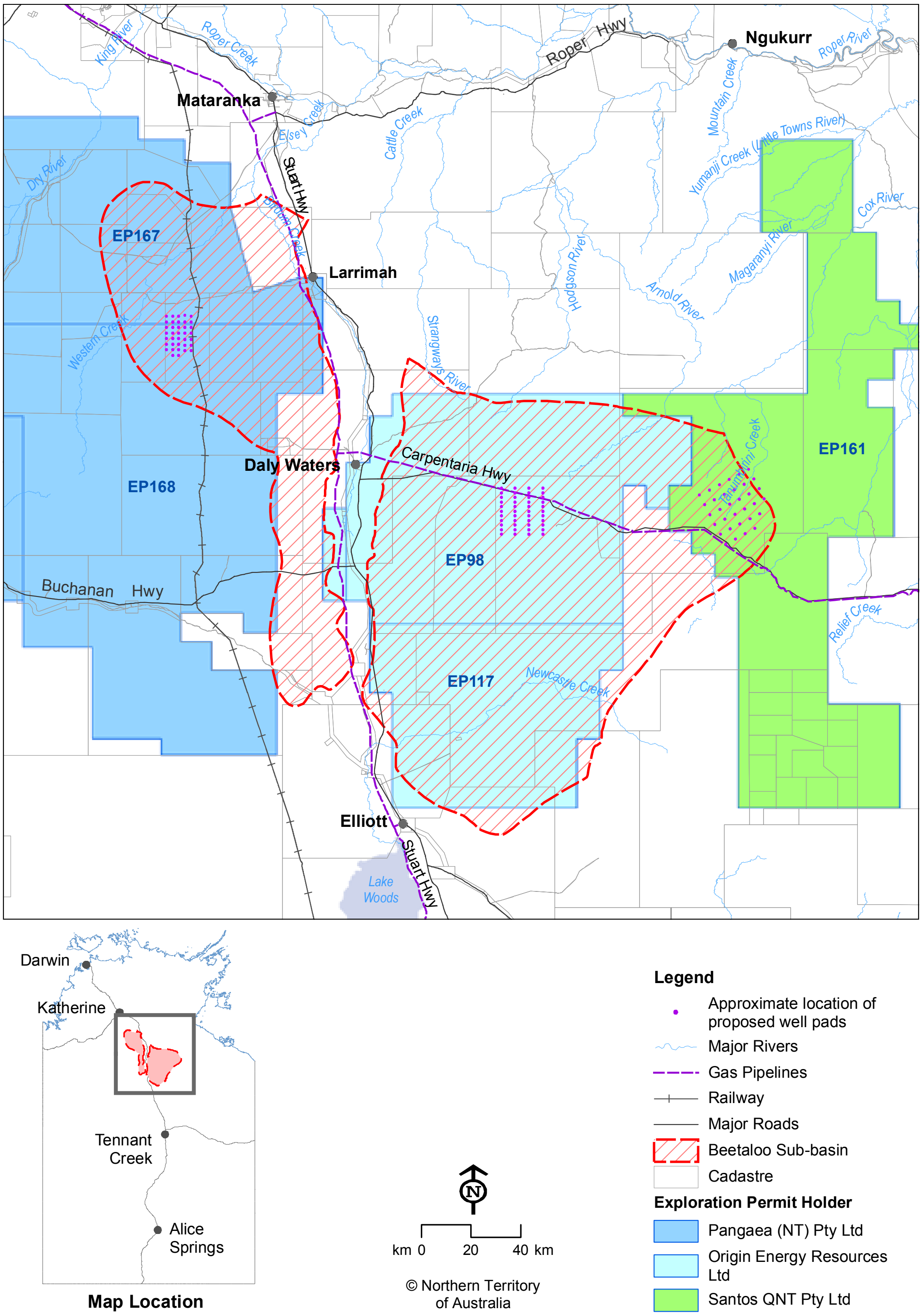
8.3 Infrastructure needs of any onshore shale gas industry in the NT

The infrastructure needs of any onshore shale gas industry will include on-site infrastructure, such as rigs for drilling and hydraulic fracturing, chemical mixing facilities, water and wastewater containment facilities, and off-site infrastructure, such as roads, pipelines, gas treatment facilities and perhaps worker accommodation.

As discussed in Chapter 7 (Section 7.3.1), the Panel has used the Beetaloo Sub-basin (**Figure 6.4**) as a case study to make a detailed assessment of water-related risks associated with an onshore hydraulic fracturing shale gas industry. The Panel has used the possible shale gas development scenarios provided by three petroleum companies - Origin, Santos and Pangaea - to develop a likely scenario of 1,000 to 1,200 wells, associated with around 150 to 200 well pads in three locations (**Figure 8.5**) over the next 25 years.

Multi-well pad infrastructure (CSG), Roma Queensland, as visited by the Panel, July 2017.

Figure 8.5: Map showing potential shale gas development scenarios in the Beetaloo Sub-basin as provided by Pangaea,[60] Origin[61] and Santos.[62]



Disclaimer: These indicative development scenarios have been recreated from submissions made to the Inquiry by Pangaea, Origin, and Santos and are indicative only. To the Panel's knowledge the proposed scenarios have not been presented to the Northern Territory Government and are not currently subject to any type of government assessment or approved process. Any interpretation of the scenarios should take into account relevant information supplied in the respective submissions.

60 Pangaea submission 427, pp 10-12. (Adapted from Figure 1: *20 year indicative development scenario utilising Pangaea's 'NT Way' approach to develop the field for social and mutual benefit).*

61 Origin submission 153, pp 35-40. (Adapted from Figure 12: *Schematic representation of a large scale development project including key activities and infrastructure statistics).*

62 Santos submission 168, pp 35-42. (Adapted from Figure 24: *Ten-well lease development concept (to scale).*

8.3.1 On-site infrastructure

During drilling and hydraulic fracturing, there is a concentration of heavy equipment on site, along with large stockpiles of drilling supplies and hydraulic fracturing chemicals. This can involve thousands of truck movements per well site over many months; directional drilling occurring over several months; and hydraulic fracturing usually taking less than one month.[63] Accordingly, to drill and hydraulically fracture 8-10 wells per pad would take approximately one year. During this time the site would comprise a drilling rig, large compressors, chemical storage facilities, water and wastewater storage ponds, and worker facilities.

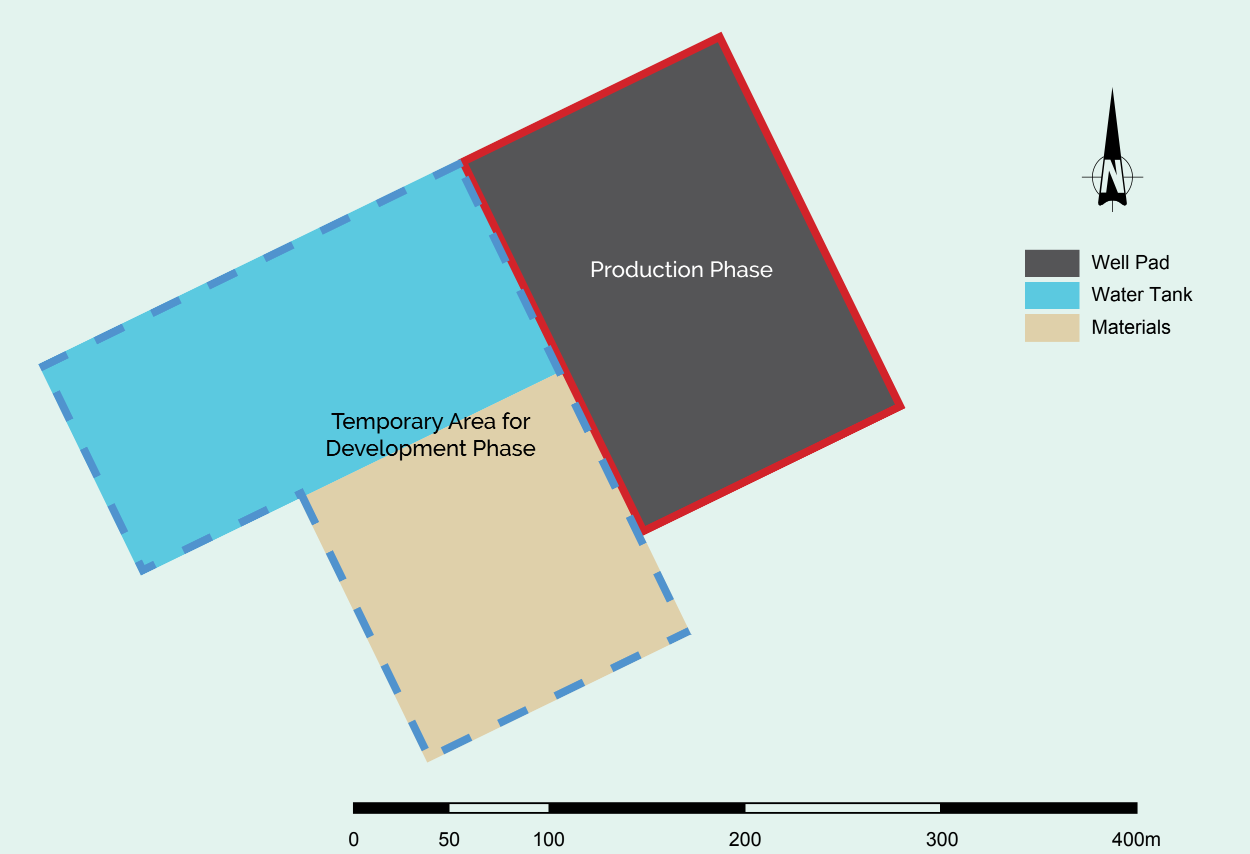
Drilling Rig at Kalala S-1 exploration well. Identical drilling rig also used at Amungee and Beetaloo well sites. Source: Origin.

After the completion of drilling and hydraulic fracturing, all heavy equipment is removed and permanent surface infrastructure constructed, including a cement well pad, a well head, a gas-water separator, a gas pipeline, storage facilities for produced water, and fencing to keep livestock and other animals away from the well.[64] The final footprint of the well and surface facilities is much smaller than the original drilling footprint.[65]

Origin provided the Panel with considerable detail of its expected on-site infrastructure needs over a 20 to 40 year period.[66] It identified three phases: exploration and appraisal (8-16 wells on 2-6 well pads over two to three years); delineation (24-48 wells on 3-6 well pads over two to four years); and development (400-500 wells on 50-65 well pads over 20-40 years).[67] Origin and Pangaea have assumed the size of each well pad during the initial two phases would be approximately 200 m x 200 m, but during production would reduce to around 100 m x 100 m.[68]

63 ACOLA Report.
64 Origin submission 153, pp 252-275.
65 Origin submission 433, p 49.
66 Origin submission 153, pp 35-44, 252-275; Origin submission 433, pp 49-52.
67 Origin submission 153, pp 35-36.
68 Origin submission 433, p 49; Pangaea submission 427, p 12; Santos have assumed a slightly large well pad area during production of 32,000 m^2; Santos submission 414, p 8.

Figure 8.6: Land use for a 10 well pad construction compared to Darwin's TIO Stadium. Source: Santos.[69]



Area used during production phase is slightly larger than a football ground (150 m x 200 m).

69 Santos submission 420, p 8.

The overall surface footprint of each development will depend upon the number of well pads and their spacing. For example, a 50 well pad development, with each pad 2 km apart, would result in a total footprint of around 500 km^2 (25 km x 20 km).[70] In addition, Origin estimated land disturbance between well pads due to pipelines (assumed to be 2.1 km long x 10 m wide) and roads (assumed to be 2.1 km long x 15 m wide). Pangaea provided indicative seismic line clearing widths of 5 m for the source lines and 3 m for the receiver lines. [71]

Therefore, the overall area of land affected by the shale gas operations of the three companies in the Beetaloo Sub-basin would be approximately 1,000 to 1,500 km^2 over the three locations out of a total area of 26,200 km^2 (that is, 4-6% of the area) (**Figure 8.5**).

Amungee NW-1H wellsite in EP98 during drilling operations (30-60 days): Source Origin.

8.3.2 Off-site infrastructure

In addition to the above on-site infrastructure, any shale gas development will require significant off-site infrastructure, such as roads, gas processing plant, and pipelines. Three types of gas pipelines will be needed: between well pads, from the well pads to gas processing plants and from these gas processing plants to either Darwin or the east coast of Australia. Additionally, it will be necessary to treat the wastewater (flowback fluids and produced water) left at the end of the hydraulic fracturing process and the produced water during the lifetime of the production phase. However, as discussed in Chapter 7, the Panel has no detail on these issues.

8.3.2.1 Roads

Origin has noted that roads and pipelines, not well pads, make up the majority of the surface footprint of onshore shale gas development in the NT.[72] It is well recognised that shale gas development will require additional roads to be constructed, and many existing roads will need to be upgraded. For example, Pangaea is progressing with the sealing of Western Creek Road (started in 2016), which will be of substantial public benefit.[73]

70 Origin submission 433, p 50.
71 Pangaea submission 220, p 42.
72 Origin submission 433, p 50.
73 Pangaea submission 427, p 11.

Origin has indicated to the Panel that access roads between well pads will be 2.1 km long and 15 m wide and will be constructed alongside buried pipelines. Accordingly, for Origin's large scale development scenario, it is estimated that an additional 40-130 km of roads will be required, representing around 0.5 to 2.0 km^2 of land disturbance.[74]

As noted in Section 8.5.2, development of an onshore shale gas industry will inevitably lead to an increase in heavy-vehicle traffic on both major and minor roads. The Panel heard the concerns from local government over who will be responsible for the maintenance of these minor roads, many of which are not sealed.[75] The gas companies have some responsibility for maintaining roads they use, but the details of exactly what this entails needs to be worked out.

8.3.2.2 Gas processing facility

Any onshore shale gas development will require a gas processing facility to dehydrate the gas to remove any remaining water and to compress the gas before it is transported (piped) to a distribution hub.[76] These are large and complex chemical engineering plants, with infrastructure that can include a considerable amount of pipelines, compressors, electrical generation equipment, water storage and treatment facilities, site offices and staff accommodation camps.[77]

Condabri Central Gas Processing Facility. Source: Origin.

The Panel has no information on the possible location of any gas processing facilities associated with the three shale gas developments proposed by Origin, Santos and Pangaea, or whether these gas companies could build and operate a joint gas processing plant.

8.3.2.3 Pipelines

Pipelines and roads will have the largest impact on the landscape, even though it is anticipated that these will be underground.[78] Origin has estimated that each well pad will require 2.1 km of pipeline and a cleared width of around 10 m. Access roads between well pads are likely to be constructed alongside the buried pipeline, these being 2.1 km long and 15 m wide.

Therefore, a 50-65 well pad development will require an estimated 250-300 km of connecting gas pipeline, with a further 60-80 km depending upon the location of the gas processing facility. Over the three potential developments mooted for the Beetaloo Sub-basin, there could be around 1,000 km of pipelines, resulting in around 10 km^2 of land clearing.

74 Origin submission 153, pp 40-41.
75 For example, Coomalie Council submission 15, p 2.
76 Origin submission 153, p 275.
77 Origin submission 153, p 275.
78 Origin submission 433, p 49.

In 2015, the Queensland Gasfields Commission undertook a major stocktake of land rehabilitation and landholder engagement practices associated with the construction of the pipelines connecting the Surat Basin gas fields with the LNG facilities in Gladstone.[79] The combined length of these pipelines, constructed between 2012 and 2015, was almost 1,500 km. Key learnings included the fact that communication with landholders was critical; levels of compensation needed to be relative to total impact; multiple pipelines required coordination and cooperation; weed management required joint effort; and fencing of easements was found to be a valued investment.[80]

8.4 Biodiversity and ecosystem health

In assessing the land related risks of any onshore shale gas industry in the NT, the Panel's objectives include ensuring that there is a low impact on the terrestrial biodiversity values of affected bioregions[81] and to ensure that the overall terrestrial ecosystem health, including the provision of ecosystem services,[82] is maintained.

There is extensive overseas scientific literature on the impacts of onshore shale gas, and other onshore oil and gas development, on terrestrial biodiversity and ecosystem health, and this has been the subject of several recent reviews.[83] However, there has been relatively little analysis of these impacts in an Australian context.[84] The Panel received a number of submissions on the potential risks of any onshore shale gas industry to terrestrial biodiversity and ecosystem health.[85]

The Panel has assessed the following risks to the protection of terrestrial biodiversity and the maintenance of healthy terrestrial ecosystems in the NT:

- the location of onshore shale gas development in areas of especially high conservation values;
- the spread of invasive species;
- the impact of changed fire regimes;
- changes to native vegetation; and
- disruption to the movement of water and nutrients due to the construction of roads and pipelines.

8.4.1 Unacceptable location of shale gas development in areas of high conservation value

The Panel believes that shale gas development should be excluded from areas where regional conservation values are high, such as areas of high biodiversity, significant levels of endemism or where there is the occurrence of threatened species. In Chapter 14, the Panel recommends that national parks and conservation reserves,[86] with appropriate buffer zones, be declared reserved blocks under s 9 of the Petroleum Act. This means that those areas will never be released for onshore shale gas exploration.

However, given that the locations of these reserves have historically not been proclaimed on the basis of any systematic evaluation of regional biodiversity assets, it cannot be assumed that they are representative of broader regional biodiversity values or are fully protective of them (Section 8.2.3).[87] Most of the NT has never been systematically surveyed for flora and fauna, largely because of its vast size and remoteness.[88] Consequently, the distributions of most species (including those formally recognised as *"threatened"*) are known only in general terms at best, and there is very limited knowledge of geographic patterns of diversity and endemism.[89] Information

79 Queensland Gasfields Commission 2015b.
80 Queensland Gasfields Commission 2015b.
81 Department of the Environment and Energy 2009.
82 Constanza et al. 1997.
83 Kiviat 2013; Brittingham et al. 2014; Souther et al. 2014.
84 A notable exception is Eco Logical Australia 2013.
85 For example, ALEC submission 88; Arid Lands Environment Centre submission 238 (**ALEC submission 238**); EDO submission 213; Environmental Defenders Office (NT) Inc, submission 456 (**EDO submission 456**); Department of Environment and Natural Resources, submission 473 (**DENR submission 473**).
86 DTC 2017.
87 EDO submission 213, p 20.
88 DENR 2016.
89 EDO submission 213, p 10.

is particularly scant for terrestrial invertebrates,[90] which represent the great majority of the NT's faunal species and which play a critical role in the functioning of ecosystems.

All onshore shale gas activities must have an approved EMP in place (see Chapter 14).[91] However, EMPs are not the appropriate tool to ensure that a comprehensive, region-wide assessment of the biodiversity values of a permit area takes place. Localised and activity-based EMPs may not identify any areas that might be biodiversity hotspots or centres of endemism within a regional context.

The Panel's assessment is that the likelihood of onshore shale gas development occurring in currently undocumented areas of high conservation value in the NT is 'high', given the lack of comprehensive and systematic information on the biodiversity assets of prospective regions,[92] including virtually no information on invertebrate fauna. This poses a significant threat to species that might occupy highly restricted ranges within a development area, and therefore, the consequence is also rated as 'high'. Combining the likelihood ('high') and consequence ('high') gives an overall risk rating of 'high'.

This high risk can only be mitigated by implementing the findings from a strategic regional assessment of biodiversity values conducted prior to any shale gas development being approved (including as part of a SREBA).

Bioregional planning based on strategic assessment is widely recognised (including by the EPA[93]) as the most appropriate basis for limiting the impacts on biodiversity of regional development, and is formally recognised under the EPBC Act, including for *"large-scale industrial development and associated infrastructure"*.[94] Strategic bioregional assessment provides the foundation for a planning framework for development that gives certainty to both industry and communities, and achieves better environmental outcomes by addressing cumulative impacts across broad regions.

The Panel's assessment is that the risk of inappropriate location of any onshore shale gas development would be acceptably low provided that a strategic regional assessment of terrestrial biodiversity values is undertaken to ensure that development is excluded from any identified areas of high conservation value. These regional assessments should be comprehensive,[95] both in terms of space (covering all major vegetation types across the region) and biota (including all groups of vascular plants and terrestrial vertebrates, and representative terrestrial invertebrates).[96] The data should be assessed for patterns of species richness and endemism, and for the occurrence of threatened species.

Recommendation 8.1

That strategic regional terrestrial biodiversity assessments are conducted as part of a SREBA for all bioregions prior to any onshore shale gas production, with all onshore shale gas development excluded from areas considered to be of high conservation value. The results of the SREBA must inform any decision to release land for exploration as specified in Recommendation 14.2 and be considered by the decision-maker in respect of any activity-based EMP.

8.4.2 Unacceptable increases in the spread or impacts of invasive species

8.4.2.1 Weeds

Nationally, weeds affect the structure and function of ecosystems and have a negative impact on native fauna and flora.[97] Weeds already pose a serious threat to biodiversity in the NT,[98] and throughout Australia's rangelands.[99] If introduced into suitable habitat, weeds can rapidly compete with, and replace, native plant communities, transforming faunal habitat. Weeds can also indirectly change ecological function by altering fire regimes, light and water availability, and soil nutrients.[100] The Territory has many established weed species that already affect

90 ALEC submission 88, p 12.
91 Origin submission 153, pp 95-96; Santos submission 168, p 165; DPIR submission 226, pp 196-201; Origin submission 433, p 56.
92 Central Australian Frack Free Alliance, submission 505 (**CAFFA submission 505**), p 7.
93 Northern Territory Environment Protection Authority submission 417 (**EPA submission 417**), p 3.
94 Australian Government 2011.
95 EDO submission 456, p 27.
96 ALEC submission 88, p 16; ALEC submission 238, p 12.
97 Invasive Plants and Animals Committee 2016, p 6.
98 NT Weeds Management Strategy 1996-2005; ALEC submission 88, p 16.
99 Grice 2006.
100 DENR 2015.

production and conservation values, and are considered to be a core challenge of broad scale land management. At least $15 million is spent each year on weed management in the NT.[101] Any onshore shale gas development has the potential to spread weeds into regions where they do not currently occur, and to exacerbate spread and density where weed establishment has already occurred (see Section 8.3 above).

The Weed Management Branch in DENR has identified petroleum exploration as a high risk pathway for weed spread, through unintentional movement of seeds, plants, plant parts, or soil containing seed, along with disturbance to the soil that increases the probability of seeds establishing.[102] DENR advised the Panel that petroleum extraction has the potential to have an adverse impact upon biodiversity through land surface disturbance, including the spread weeds,[103] and multiple submissions to the Panel identified this risk.[104] Submissions from pastoralists specifically identified weed introduction and/or spread as a problem that should not become their responsibility, or affect carrying capacity and land condition.[105]

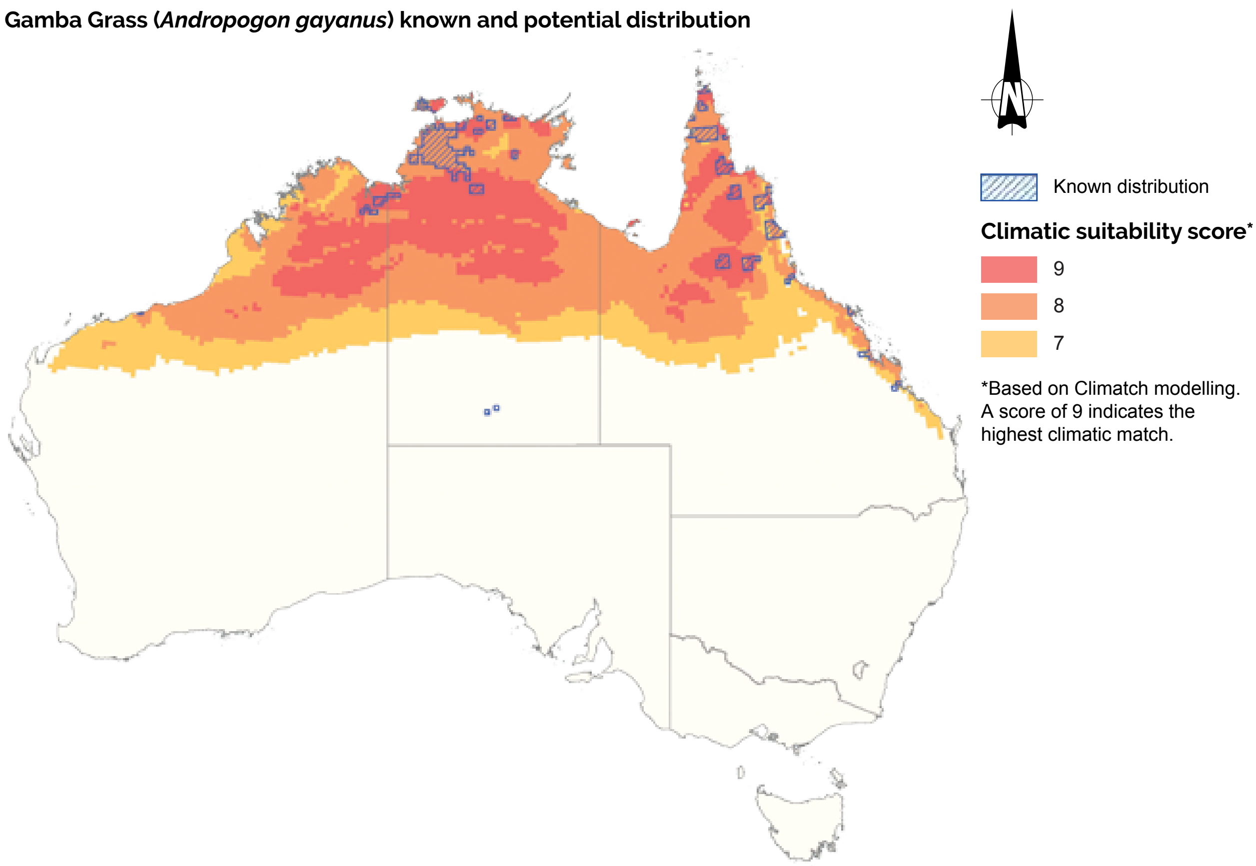
In July 2017, the Panel travelled to Queensland to gain a better understanding of the implications of CSG development in that State (see Appendices 5 and 6). AgForce indicated that biosecurity risks were among the greatest concerns for rural landholders with CSG activity on their property.[106] Similarly, landholder social impact analyses and case studies indicate that weed monitoring and prioritised management of establishing weeds divert resources away from standard farm operations.[107] Through the Inquiry's submission process, Lock the Gate Alliance noted that African love grass infestations, believed to have been introduced by gas companies, had affected productivity, profitability and land value.[108]

The Sturt Plateau is highly regarded as relatively free of weeds,[109] but a number of high risk species not yet established in the NT are known to be climatically suited to the region. These include weeds of national significance, such as parthenium (*Parthenium hysterophorus*) [110] and rubber vine (*Cryptostegia grandiflora*).[111] In addition to their ecological impacts, these weeds would have severe implications for pastoralism. Both parthenium and rubber vine are toxic if ingested by stock, and parthenium can also produce serious allergic reactions in humans, including dermatitis, hay fever and asthma.[112] Grader grass (*Themeda quadrivalvis*) is already well established on many pastoral properties in the Katherine and Roper Districts. This weed presents a range of challenges for landholders due to its competitiveness, short time frame to maturity and inaccessibility during optimal control periods.[113] Once established, the impacts of grader grass include reduced productivity, increased high intensity fires, and increased management costs.[114]

For some weeds, the resource implications on conservation and Aboriginal managed lands may be greater because grazing is not a management option. In northern Australia, gamba grass (*Andropogon gayanus*), was deliberately introduced as a highly productive and palatable fodder, but has since proved to be highly invasive and damaging.[115] Gamba grass is now declared and recognised as a weed of national significance. It is extremely tall (up to 4 m) with exceptional herbaceous biomass, and this fuels fires of unprecedented intensity in the natural landscape that cause major declines in tree cover and subsequent ecosystem functioning.[116] These fires represent a significant threat to people's lives and property.[117] Gamba grass and two species of mission grasses are recognised as key threatening processes under the EPBC Act. **Figure 8.7** shows the known and potential distribution for gamba grass in Australia.

101 DENR 2015.
102 DENR 2015.
103 DENR submission 230, p 9.
104 Lock the Gate submission 171, p 27; EDO submission 213, pp 7, 11-12.
105 D Tapp submission 11, p 3; NTCA submission 217, p 3; Consolidated Pastoral Company Pty Ltd, submission 218 (**CPC submission 218**), p 7.
106 Queensland Gasfields Commission 2017, p 56.
107 GISERA 2016a.
108 Lock the Gate submission 171, p 27.
109 DENR 2017.
110 Agriculture and Resource Management Council of Australia and New Zealand et al. 2001.
111 Australian Weeds Committee 2012.
112 Agriculture and Resource Management Council of Australia and New Zealand et al. 2001.
113 Pastoral Land Board 2015.
114 Keir and Vogler 2006, p 197.
115 DENR 2014.
116 Rossiter et al. 2003.
117 Setterfield et al. 2013.

Figure 8.7: The known and potential distribution for gamba grass in Australia. Source: Australian Government.[118]



Gamba grass spreading along an access track (new growth showing on perennial plants)

Gamba grass fire (late season controlled hazard reduction burn)

118 SEWPaC 2012b.

In arid and semi-arid regions of the NT, buffel grass (*Cenchrus ciliaris*), an undeclared grass used for pasture improvement and soil stabilisation in central Australia,[119] produces a high fuel load that supports more frequent and intense fires than these arid landscapes would otherwise experience.[120] The impacts of buffel grass fires on ecosystem function and biodiversity include the loss of keystone (and iconic) species such as river red gums (*Eucalyptus camaldulensis*).[121]

Weeds are currently regulated under the Weeds Act (administered by DENR), and there is also capacity for the Petroleum Environment Regulations (administered by DPIR) to regulate weeds on petroleum permits. The Panel requested information from DENR and DPIR to determine how the current legislative structure is jointly administered, including monitoring, compliance and enforcement.[122] The combined response revealed a number of deficiencies, namely:

- only *"owners"* and *"occupiers"* are obliged to comply with statutory weed management plans under the Weeds Act, and gas companies are neither.[123] This means that even though gas companies can access, traverse and develop land, they do not have to comply with the same legal obligations as the underlying tenure holder to manage weeds;
- the Petroleum Act allows the Minister to place conditions on a petroleum interest.[124] For example, that, *"the permittee shall take such steps as are reasonably practical to prevent the spread of noxious weeds, including the washing down of vehicles and removal of grass seeds before moving vehicles and equipment to a new area."* [125] However, it is currently not a condition that there must be compliance with a statutory weed management plan; and
- under the Petroleum Environment Regulations, all *"regulated activities"* (those with an environmental impact, irrespective of how small) must have an EMP in place.[126] Therefore, if there is a risk of weeds spreading as a result of an activity then the tenure holder must have a weed management plan as part of its EMP.[127] However, walking or driving on existing roads or tracks for the purposes of taking water or rock samples are exempt from these requirements. Such activities can nevertheless result in the introduction and spread of weeds, and should not be exempt from the requirement to have a weed management plan in place.

In assessing the risk of the spread of invasive weeds by any onshore shale gas industry, the Panel has assumed that an acceptable risk is no incursion of new non-native plant species into any potential onshore shale gas development area, and no spread of non-native plant species that already occur in that area.

The Panel's assessment is that the likelihood of significant spread of invasive weed species is 'high', because of the large number of additional personnel (company and contractors), vehicles, and vehicle trips that will be associated with any onshore shale gas development, and the limitations of the current weed management regulations. Even with best management practice in place (particularly with regard to hygiene, for example wash-down bays), the Panel is of the view that the introduction of new species is likely. The chances of weed establishment before detection and control will be increased because of the remote location of these developments and the seasonal inaccessibility of the areas. In addition, monitoring and compliance will require considerable resources because of the potential distances and seasonal inaccessibility involved. The Panel has also assessed the consequences of the spread of invasive weed species as 'high' because such species have a history of significant impact on terrestrial ecosystems and other land uses in the NT. This gives an overall risk rating of 'high'.

Strengthening the current regulatory regime should mitigate the risk of the spread of weeds. For example, gas companies could be made expressly liable for any non-compliance with statutory weed management plans by placing a condition on an EMP.

It is currently open to the Minister to place conditions on any EMP. While gas companies are not *"owners"* or *"occupiers"* under the Weeds Act, the *Northern Territory Weeds Management*

119 Edwards et al. 2008, p 111.
120 Marshall et al 2012, p 8.
121 Edwards et al. 2008, p 111.
122 Department of Primary Industry and Resources and Department of Environment and Natural Resources, submission 419 (**DPIR and DENR submission 419**).
123 Weeds Act, s 9(2).
124 See, for example, Petroleum Act, s 20(5).
125 Department of Primary Industry and Resources, submission 281 (**DPIR submission 281**), Attachment A, p 7.
126 DPIR 2016, p 8.
127 DPIR submission 226, p 198.

Strategy 1996-2005, makes it clear that industries responsible for the spread of weeds should be responsible for their management. The Panel agrees.

The Panel is of the view that weed spread prevention is the best approach to weed management. The Queensland experience shows that there is considerable value in anticipating some weed introductions and having an agreed process for management already in place. The Panel's opinion is that a baseline assessment of weeds must occur prior to any onshore shale gas exploration activities commencing to monitor the types and extent of weeds already in existence to determine whether new species have been introduced or whether existing weed species have spread. The locations of weeds will also inform property and region-specific requirements for wash downs.

In circumstances where onshore shale gas infrastructure is constructed in areas already covered by an existing weed management plan, collaborative approaches to the prevention and management of weed spread should be negotiated with and between gas companies. The Panel recommends shale gas companies identify a dedicated weeds officer whose role is to monitor well pads, roads and pipeline corridors for weeds. Additionally, all field workers should receive training in the identification of weeds, especially gamba and grader grass, and to report any suspected incursions to the weeds officer.

With the above mitigation measures in place, it is the Panel's view that the likelihood of significant incursions of invasive weed species will be substantially reduced. Ongoing monitoring and management will result in the detection and control of any incursions. This will result in a low threat of the spread of invasive species as a result of any onshore shale gas development.

Recommendation 8.2

That a baseline assessment of all weeds within a permit area be conducted prior to any onshore shale gas exploration or development and that ongoing weed monitoring be undertaken to inform any weed management measures necessary to ensure no incursions or spread of weeds. Gas companies must have a dedicated weeds officer whose role is to monitor well pads, roads and pipeline corridors for weeds.

Recommendation 8.3

That gas companies be required to have a weed management plan in place prior to entering onto a petroleum permit. The plan must be consistent with all relevant statutory weed management plans and relevant threat abatement plans established under the EPBC Act.

8.4.2.2 Invasive ants

Exotic invasive ants are among the world's worst invasive species. Two species are already established in certain areas of the NT, with substantial impacts on native biodiversity:[128] the African big-headed ant (*Pheidole megacephala*) and the Yellow crazy ant (*Anoplolepis gracilipes*). Additionally, two other tropical exotic ants with serious environmental impacts elsewhere in the world, the Red imported fire ant (*Solenopsis invicta*) and the Little fire ant (*Wasmannia auropunctata*) exist in Queensland,[129] and therefore, have high potential for introduction into the NT.

The Panel has determined that there should be no incursion or spread of invasive ants by any onshore shale gas industry.

The Panel assessed the likelihood of this occurring as 'medium', and the consequence as 'high', giving an overall risk rating of 'high'. However, exotic ant species are spread in the same way as weeds, namely, by transport of contaminated vehicles and equipment, and poor hygiene procedures. Measures that prevent the spread of weeds would therefore also mitigate the risk of spread of exotic ants. Such measures must be included in an EMP for an onshore shale gas activity where the spread of invasive ants is a risk associated with that activity.

8.4.2.3 Feral animals

There is considerable evidence that feral animals are causing major environmental damage in the NT.[130] For example, Arabian camels, cane toads, cats, dogs, donkeys, foxes, pigs and horses

128 Hoffmann et al. 2009; Hoffmann and Saul 2010.
129 Lach and Barker 2013.
130 Craggs 2016.

are all known to be present in the Sturt Plateau bioregion, with camels, donkeys and horses present in high numbers, affecting the vegetation and water sources. Additionally, cane toads, cats, dogs and foxes are affecting biodiversity, but their distribution and the extent of their impact is uncertain.[131] Wild dog impacts on cattle production and management costs are significant, including on stations in the Sturt Plateau.[132]

However, these feral animals are already well established in the NT, and whether any onshore shale gas industry would affect the population dynamics or impacts of existing feral animals is unclear. A report by Bali suggests that the impact of feral cats and cane toads, particularly on already threatened species, may be increased due to the increased number of roads and cleared pipeline corridors.[133] The Panel notes that landholders in regions with gas development potential have legislative obligations to control feral animals.[134] In addition, there are TAPs established under the EPBC Act that apply to foxes, cats, pigs and cane toads.

The Panel is of the view that the risk of increased impacts from feral animals due to any onshore shale gas industry is 'low' and acceptable.

8.4.3 Unacceptable changes to fire regimes

As noted above, the development of any onshore shale gas industry in the NT will require the construction of a comprehensive interconnected network of access roads and linear infrastructure within previously contiguous landscapes. This could have considerable and varying influences on fire regimes including increases in the number and timing of ignitions (both accidental and deliberate), barriers to fire spread, and potential changes to fire intensity as a result of higher likelihood of invasion by grassy weeds. Potential changes to fire regimes are considered below in regard to biophysical changes to the environment and to the existing fire management aspirations and programs of tenure holders.

Fire is a much more important issue for any shale gas development in the NT than is reflected in the overseas literature.[135] The biota of the NT has a long evolutionary history with fire and is adapted to the habitat conditions created by it. Fire frequency is highest in the tropical savannah landscapes of northern Australia, which cover both the northern and central regions of the NT.[136] In the central and northern regions of the NT, including the Sturt Plateau, annual monsoonal rains generate considerable vegetative growth, which cures rapidly with the onset of each dry season to create vast areas of fuel. Hundreds of thousands of square kilometres within these areas are burnt each year, with most areas burnt every two to five years (**Figure 8.8**). DENR describes frequent, late season, large scale fires as a constant risk in the Sturt Plateau, Gulf and northern Barkly areas.[137]

Savannah fires are also important for Australia's carbon accounts because they release substantial amounts of greenhouse gases.[138] The use of prescribed burning to reduce fire extent and intensity, and therefore greenhouse gas emissions, is emerging as a significant economic activity across northern Australia, especially for remote Aboriginal communities.[139] The Environment Centre NT has raised concerns that an onshore shale gas industry will have an impact on successful existing Aboriginal fire management programs. [140] In May 2017 there were 17 savannah burning carbon projects registered in the NT, with two of these occurring in the Beetaloo Sub-basin.[141]

Fire is less frequent in arid regions of the NT, with the interval between fires usually ranging from seven to 20+ years (**Figure 8.8**), driven by the high production of annual grasses that follows periods of unusually high rainfall.[142] An exception to this fire pattern occurs in landscapes dominated by the introduced pasture, buffel grass.[143] Buffel grass dries off between periods

131 Baker et al. 2005; EDO submission 213, Appendix D, p 13.
132 Commonwealth of Australia 2011. Wicks 2014.
133 EDO submission 213, Appendix D, p 13.
134 *Territory Parks and Wildlife Conservation Act* (NT), s 31(3).
135 Bradstock et al. 2012.
136 Andersen et al. 2003; DENR submission 473, p 1.
137 DENR submission 473, p 1.
138 Cook and Meyer 2009.
139 Russell-Smith et al. 2009; Russell-Smith et al. 2013; Richards et al. 2012.
140 Environment Centre Northern Territory, submission 188 (**ECNT submission 188**), p 6.
141 Territory Natural Resource Management 2016, p 5.
142 Edwards et al. 2008, p 111.
143 Edwards et al. 2008, p 111.

of growth enabling a high volume of dry plant matter to accumulate, which can fuel intense fires. Resilience to fire enables buffel grass to survive and quickly produce new growth after burning, providing fuel for more fires. Wildfires fuelled by buffel grass are particularly damaging to many central Australian native plant species, including trees, which are unable to cope with the increased fire intensity and frequency. They are also damaging to riparian systems and high conservation value aquatic ecosystems.[144] Additionally, these wildfires can result in serious economic losses, particularly in regions where effective fire management strategies are absent, including loss of cattle, reactive investment in fire fighting, damage to infrastructure, and loss of pasture that requires cattle to be moved, agisted or sold at sub-optimal times.[145]

Landscape fire management is integral to Aboriginal culture, playing a fundamental role in hunting, the collection of bush tucker and fulfilling land stewardship responsibilities. Fire management also plays a key role in contemporary land management. This includes the management of conservation lands throughout the NT[146] and the management of pastoral lands by preventing wildfires, improving pasture, managing grazing, and controlling weeds.[147]

Fire can have different impacts on different terrestrial ecosystems. For example, the savannah biota of the NT need frequent fires, being adapted to the open habitat conditions created by fire, such that long term fire exclusion and subsequent canopy closure leads to substantial biodiversity loss. However, the savannah landscapes also include vegetation types that require lower fire frequency.

Changes in fire regimes, particularly a high frequency of intense wildfires, can have serious impacts on vegetation, biodiversity, cultural and sacred sites, pasture and physical infrastructure.[148] For example, bullwaddy communities are extremely sensitive to frequent and intensive fires. Without management of the fire regime there can be a change in the vegetation communities from bullwaddy through to lancewood and then to a eucalypt dominated woodland. This process may be accelerated or exacerbated by the invasion of exotic pasture grasses such as buffel grass.[149]

Fire across the non-urban areas of the NT is managed under the Bushfires Management Act,[150] with statutory Regional Management Plans (**RMPs**) currently being developed in four of the five Fire Management Zones. These RMPs are developed in consultation with landholders and other stakeholders. They focus on a range of outcomes, including the protection of lives, property, assets and environmental values, and take into account how fire regimes vary according to climate, vegetation, land tenure, and land use.

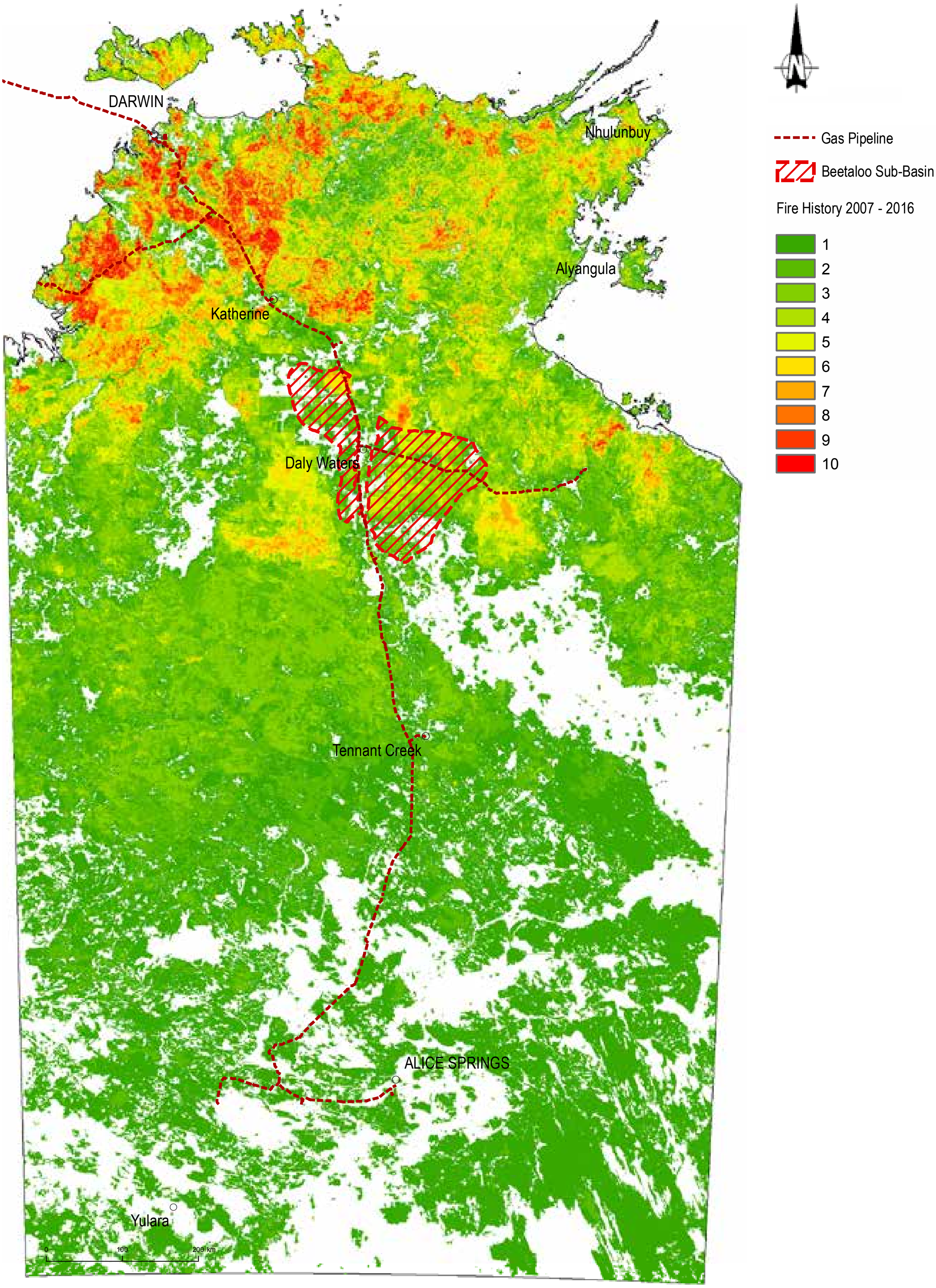
The Panel notes that the current NT legislative requirements regarding weeds, feral animals and fire are focussed on landowners and land managers and not gas companies. But it is highly desirable that the gas companies understand and comply with these requirements.

The additional access roads and pipeline corridors needed by gas companies can have a considerable and varying influence on fire regimes in the NT, including:

- by increasing traffic, and therefore, the number and timing of deliberate or accidental ignitions. Edwards et al. have noted that changing fire regimes in the NT often result in *"a concomitant increase in the number of fires associated with roads"*;[151]
- by increasing the risk of fire due to flaring, the process of burning gas for operational or safety reasons. The Panel notes that in NSW, the EPA allows flaring of gas during total fire bans provided that companies have an exemption under the *Rural Fires Act 1997* (NSW);[152] and
- by reducing the spread and areal extent of fire due to physical barriers provided by additionally cleared roads and pipeline corridors. However, these activities are unlikely to reduce the incidence of fire sufficiently to threaten the fire-adapted savannah biota,[153] and fire-related conservation issues in the NT concern too much, rather than too little, fire.[154]

144 Northern Territory Government 2011.
145 Edwards et al. 2008.
146 Dyer et al. 2001, pp 3-4.
147 Department of Primary Industry and Fisheries 2010, p 62.
148 Edwards et al. 2008, p 111.
149 Parks and Wildlife Commission of the Northern Territory 2005, p 19.
150 DENR submission 473, p 2.
151 Edwards et al. 2008.
152 NSW Government 2005, Barker 2015.
153 Andersen et al. 2012; Abreu et al. 2017.
154 Andersen et al. 2005.

Figure 8.8: Map of fire frequency between 2007 and 2016 in the NT. Source: DENR.



Aerial photo of a station on the Barkly Tablelands illustrating the capacity of access tracks to influence the path and extent of fire. Source: Scott Bridle, Australian Outback Photography.

The Panel's assessment is that any onshore shale gas industry is likely to have greater impact on fire frequency in the tropical savannah landscapes of the central and northern regions of the NT, rather than in arid regions, because of the fuel available for fire every year in those regions.[155] However, the Panel is aware that while there is a lack of fuel in arid regions in most years, when fuel has accumulated over time, wildfires can cause serious ecological and economic damage unless active management is in place to reduce fuel loads.

The Panel has assessed the likelihood of increased fire frequency due to any onshore shale gas industry as 'medium', given increased human activity, and therefore, sources of ignition. This increase is likely to exacerbate the impact of feral cats on small mammals,[156] threaten fire sensitive ecological communities such as lancewood,[157] and lead to increased greenhouse gas emissions.[158] The Panel's assessment is therefore that the consequence of increased fire frequency is 'high', giving an overall risk rating of 'high'.

DENR is currently developing RMPs for each of the NT's five fire management zones, as required under the Bushfires Management Act.[159] These RMPs will specify arrangements for the mitigation, management and suppression of fire. Consultation has begun on four of the five RMPs (Savannah, Vernon Arafura, Arnhem and Alice Springs), with any onshore shale gas industry identified as a potential risk in all four regions. DENR has advised the Panel that this risk will be addressed under DENR's established risk matrix, and mitigation strategies developed where appropriate.[160]

Possible actions that could mitigate the risk of increased fire frequency include:

- limiting ignitions, including those due to smoking by gas industry employees in the field;
- ensuring that an RMP is developed and implemented by all relevant landholders, including gas companies;

155 Nano et al. 2012.
156 Andersen et al. 2012; Davies et al. 2017.
157 Woinarski and Fisher 1995.
158 Cook and Meyer 2009.
159 DENR submission 473, p 2.
160 DENR submission 473.

- undertaking annual fire mapping to monitor any increase in fire frequency due to any onshore shale gas industry, compared with a baseline established for at least the decade prior to commencement of any onshore shale gas development, using remotely sensed information that is readily available on the North Australian Fire Information website;[161] and
- implementing management actions, such as prescribed fuel reduction burns at strategic locations, to reduce fuel loads and protect key values and assets if required on the basis of annual fuel monitoring data.

If these mitigation measures are implemented and enforced, the Panel's assessment is that the risk of changed fire regimes would be 'low' and acceptable.

Recommendation 8.4

That gas companies be required to comply with any statutory regional fire management plan. The fire management plan should:

- ***address the impact that any onshore shale gas industry will have on fire regimes in the NT, and how those impacts should be managed;***
- ***establish robust monitoring programs for assessing seasonal conditions and fuel loads;***
- ***require that annual fire mapping be undertaken to monitor any increase in fire frequency due to any onshore shale gas development;***
- ***require baseline data to be established for at least the decade prior to commencement of any onshore shale gas development; and***
- ***require the implementation of management actions, such as prescribed fuel reduction burns at strategic locations, to reduce fuel loads and protect key values and assets if required on the basis of the annual fuel monitoring data.***

8.4.4 Unacceptable changes to native vegetation

Any onshore shale gas development will inevitably involve substantial vegetation clearing given that the NT is almost entirely covered by native vegetation.[162] Clearing of vegetation for infrastructure (well pads, roads, pipeline corridors) will result in direct habitat loss and in the fragmentation of fauna habitat not directly cleared.[163]

The current industry practice of multiple wells with extensive laterals results in substantially less vegetation clearing compared with past practices where individual wells were spread over a much greater surface area. The Panel has estimated the total area cleared within a development area for a range of well pad densities, based on assumptions of initial well pad size and lengths, and the widths and lengths of access roads and pipelines (**Table 8.1**). The Panel has not included areas cleared for exploration seismic lines. It is estimated that these lines need cleared widths of 5 m, for source lines, and 3 m for receiver lines.[164] The data in Table 8.1 shows that the estimated percentage of total area cleared in development areas when well pads are spaced by 1 km, 3 km and 5 km are 13%, 2.6% and 1.3%, respectively.

Industry forecasts are for well pad densities of one per 10-20 km^2 (equating to an average spacing between well pads of 3.2 to 4.4 km),[165] which would require vegetation clearing of approximately 1.5 to 2.5% of the development area, based on the figures in **Table 8.1**. Origin has estimated that the total surface footprint under their large scale development scenario would be 2% of the total development area,[166] while Santos has estimated a surface footprint of 1.4% of the total development area during the exploration and drilling phase, reducing to 1.2% during production following rehabilitation.[167] DPIR estimates a 3.7% surface footprint during exploration and development, reducing to 0.8% during the production phase.[168]

161 Department of the Environment and Energy 2017k.
162 Eco Logical 2013, pp. 16-19; EDO submission 213, Attachment D.
163 Racicot et al. 2014.
164 Pangaea submission 220.
165 Origin submission 153, p 37; Santos submission 168, pp 38-42.
166 Origin submission 153, p 36.
167 Santos submission 420, pp 5-9. This assumes a well pad density of approximately one well pad per 19.4 km^2.
168 DPIR submission 424, pp 8-9.

Table 8.1: Estimated areas of vegetation clearing required for different densities of well pads (one well pad per 1, 9 and 25 km^2) over a development area of 2,500 km^2. Industry forecasts are for each well pad to service an area of 10-20 km^2.

Area serviced per well pad	1 km^2	9 km^2	25 km^2
Well pad spacing (km)	1	3	5
Number of well pads	2,500	256	100
Well pad clearing at 10 ha/pad (km^2)	250	25	10
Total length of roads (km)	2,700	1,600	900
Road clearing at 20 m width (km^2)	54	31	18
Total length of pipelines (km)	2,300	800	500
Pipeline clearing at 10 m width (km^2)	23	8	5
Total clearing (km^2)	330	64	33
Total clearing (% total area (2,500 km^2))	13	2.6	1.3

Vegetation clearing can also result in the fragmentation of faunal habitat,[169] with the proliferation of habitat edges, with edge effects on the abiotic environment (including microclimate, light and wind) known to occur up to 500 m or more from cleared areas.[170] In the US, it has been estimated that the loss of core habitat through edge effects associated with onshore gas development can be at least twice that lost directly through vegetation clearing.[171] A 4.5% loss in forest cover in the central Appalachians due to shale gas development has been assessed as translating to a 12% loss in core forest once edge effects are considered, and this had a detectable impact on local bird communities.[172] Habitat loss and fragmentation can be a particularly important issue when development areas cover a substantial portion of the distributions of legislatively listed threatened species.[173]

Most studies of fragmentation and edge effects have been conducted in forests, and their extent in more open habitats, such as those occurring in much of the NT, are poorly known. In open habitats, naturally clear areas will not be so ecologically different from small, anthropogenic clearings. The role of patch ensembles or mosaics in heterogeneous landscapes remains poorly understood.[174] Similarly, the understanding of gap width effects on habitat fragmentation is also largely based on studies of forests and similar habitat types that favour species with limited movement ability. [175] The Panel is unaware of any equivalent studies in Australia's savannah or desert landscapes.

The Panel notes Origin's suggestion that, *"the bioregion is considered an appropriate unit with which to assess the level of loss and/or fragmentation of habitat for fauna on a 'regional' scale".*[176]

The Panel concludes that the likelihood that an onshore shale gas development will lead to excessive native vegetation loss is 'high' at both the development and regional scales given that substantial areas will be cleared of vegetation. The consequences of this vegetation loss have been assessed as 'low', however, because only a small proportion of the landscape will be cleared and fragmentation and edge effects are therefore likely to be limited. The Panel's assessment is that it is not possible to determine the risks from habitat fragmentation and edge effects due to vegetation loss along linear corridors until there is better understanding of the sensitivities and critical effects thresholds for NT vegetation types. However, the Panel believes that it will be considerably lower than in forest habitats. The overall consequence of vegetation loss and habitat fragmentation loss is expected to be relatively low, even when accounting for cumulative impact. Therefore, the Panel's assessment of the overall risk of unacceptable changes to native vegetation is 'medium'.

169 Racicot et al. 2014.
170 Zipperer 1993; Harper et al. 2005.
171 Slonecker et al. 2012.
172 Farwell et al. 2016.
173 Gillen and Kiviat 2012.
174 Fischer and Lindenmayer 2007.
175 Lindenmayer 2008.
176 Origin submission 153, p 96.

Discussed below are a number of ways that the impact of vegetation and habitat loss can be mitigated. With these mitigation measures in place, the Panel considered that the risk of unacceptable changes to native vegetation will be 'low' and acceptable. These mitigation measures include:

- improved information on key habitat patches at the regional scale that should be avoided by any infrastructure development. This should be part of any SREBA;
- the identification of key biodiversity patches, rare or threatened vegetation patches, or individual specimens along proposed corridors, with a requirement that they be avoided in corridor routes;
- limiting the surface footprint, and therefore, the extent of land clearing through efficient design of access roads and pipeline corridors, and through region wide planning, including the co-location of shared infrastructure by different gas companies (see also Section 8.6);[177]
- monitoring any threatened species at risk by habitat fragmentation, and implementing appropriate management plans if needed;
- the effective rehabilitation of cleared areas immediately upon the completion of development, such that vegetation is re-established and edge and fragmentation effects are ameliorated; and
- appropriate offsetting to compensate for loss of vegetation and faunal habitat.

An environmental offset is an action taken to compensate for unavoidable, negative environmental impacts that result from an activity or a development. Environmental offsets apply when the impacts of development cannot be avoided or mitigated. As noted by the EDO:

> *"from a bioregional planning perspective, it would be much more proactive and precautionary to nominate priority no go areas prior to the development of shale gas fields; these would form the core conservation areas to which future additions, including offsets, can be made".* [178]

The Panel has made recommendations with regard to 'no go zones' in Chapter 14. In the event an environmental risk cannot be avoided or mitigated, environmental offsets should also be considered. The Government does not currently have an offset scheme, and the EAA makes no provision for environmental offsets or social or other community benefit as a part of any petroleum assessment or approval process. The EPA has published guidelines on environmental offsets and associated approval conditions.

The Panel recommends that the Government develop and implement an environmental offset policy to ensure that where environmental impacts and risks are unable to be avoided or mitigated, they are offset. The Panel recognises that for offsets to be effective, there must be a scientific approach to assessing the impact of development on biodiversity. The composition, structure and function of ecosystems, including threatened species, populations and ecological communities and their habitats, must be properly assessed.[179] Offsets may involve land where a suitable parcel of land is identified for protection and management. Alternatively, a management approach may be formulated that will benefit a specific species or ecosystem that is being affected by the proposed development.

Where offsets are negotiated for areas of undeveloped land, the location, size and management of those offsets should be calculated using known biodiversity values rather than simple offset ratios (for example, 1:1 hectares or square kilometres). This is particularly relevant to any onshore shale gas development where the area of cleared land is disproportionate the entire development area and scale of activity.

The Panel notes that offset arrangements can be highly variable and innovative. For example, the Panel is aware of partnership agreements between traditional owners, Indigenous ranger groups and industry for the purposes of offsetting greenhouse gas emissions through strategic fire management in the NT.[180]

177 Eco Logical 2013, p 29; BC Oil and Gas Commission 2017, p 13.
178 EDO submission 213.
179 NSW Department of Environment, Climate Change and Water 2009.
180 Tropical Savannas CRC 2017.

Recommendation 8.5

That as part of a SREBA, a study be undertaken to determine if any threatened species are likely to be affected by the cumulative effects of vegetation and habitat loss, and if so, that there be ongoing monitoring of the populations of any such species. If monitoring reveals a decline in populations (compared with pre-development baselines), management plans aimed at mitigating these declines must be developed and implemented.

Recommendation 8.6

That the area of vegetation cleared for infrastructure development (well pads, roads and pipeline corridors) be minimised through the efficient design of flowlines and access roads, and where possible, the co-location of shared infrastructure by gas companies.

Recommendation 8.7

That well pads and pipeline corridors be progressively rehabilitated, with native vegetation re-established such that the corridors become ecologically integrated into the surrounding landscape.

Recommendation 8.8

That to compensate for any local vegetation, habitat and biodiversity loss, the Government develop and implement an environmental offset policy to ensure that, where environmental impacts and risks are unable to be avoided or adequately mitigated, they are offset.

Recommendation 8.9

That the Government consider the establishment and operation of local Aboriginal land ranger programs to undertake land conservation activities.

8.4.5 Roads and pipelines as ecological barriers and corridors

As noted in Section 8.4.4, the construction of roads and pipelines could potentially cause substantial habitat fragmentation as well as intersect important vegetation or habitat features in the landscape if not designed to minimise these impacts. Additionally, pipeline corridors and roads can disrupt important ecological processes, by and including (see Section 7.6.8):

- the flow of water, sediment and nutrients across landscapes.[181] This can relate to water flow along drainage and creek-lines, or to the smaller scale run-off or run-on dynamics that are especially important in flat, semi-arid landscapes;[182]
- accelerating, or otherwise altering, runoff and/or erosion processes due to the alteration of flow, geomorphic characteristics or vegetation cover, creating potential sedimentation and turbidity threats and flow connectivity related threats;
- the spread of fire, which is an ecologically important agent of natural disturbance in many parts of the world[183] and a key driver of global vegetation dynamics;[184]
- the clearing of vegetation or habitat components that provide productivity hotspots, seasonal refugia or regionally significant feeding and breeding resources (see Section 8.4.4);
- the movement of fauna[185] (see Section 8.4.4);
- facilitating the spread of weeds along the road and pipeline corridors by transport on equipment and by providing disturbed ground for weeds to become established in (see Section 8.4.2.1); and
- acting as corridors to facilitate movement and hunting by predators (with cascading effects on their prey),[186] as well as the spread of exotic animals.[187]

181 Drohan and Brittingham 2012; Brittingham et al. 2014.
182 Ludwig et al. 1996; Eco Logical 2013, pp 21-22.
183 Bowman et al. 2009.
184 Bond et al. 2005.
185 Machtans 2006.
186 Howell et al. 2007; Latham et al. 2011.
187 Brown et al. 2006.

Given the biodiversity value of the large scale, relatively intact ecosystems of the NT, if corridor impacts are substantial over the geographic scale of the likely development scenarios discussed above, the Panel's assessment is that the consequences would be 'medium' and the likelihood, given the uncertainty for savannah and grassland ecosystems, 'medium'. Therefore, with no further mitigation, the overall assessment of risk would be 'medium', and unacceptable.

There are, however, a number of measures that could assist in mitigating these risks, including that:

- environmental legislation requires gas companies to identify critical habitats during corridor construction and select an appropriate mechanism to avoid detrimental impact on them;
- corridor widths should be kept to a minimum, with pipelines and other linear infrastructure buried, except for necessary inspection points, and the disturbed ground revegetated;
- directional drilling under stream crossings be used in preference to trenching unless geomorphic and hydrological investigations confirm that trenching will have no detrimental impact on water flow patterns and waterhole water retention timing; and
- roads and pipeline surface water flow paths minimise erosion of exposed (road) surfaces and drains, and comply with design for fauna passage at all corridors should be constructed to minimise the interference with wet season stream crossings and comply with relevant guidelines such as the International Erosion Control Association *Best Practice for Erosion and Sediment Control* and the Australian Pipeline Industry Association *Code of Environmental Practice 2009.*

With these mitigation measures in place, the Panel's assessment is that the likelihood of corridor impacts would remain, but that the consequence would be minor to moderate with an overall risk of 'low' and acceptable.

Recommendation 8.10

That environmental legislation include a requirement for gas companies to identify critical habitats during corridor construction and select an appropriate mechanism to avoid detrimental impact on them.

Recommendation 8.11

That corridor widths be kept to a minimum, with pipelines and other linear infrastructure buried, except for necessary inspection points, and the disturbed ground revegetated.

Recommendation 8.12

That directional drilling under stream crossings be used in preference to trenching unless geomorphic and hydrological investigations confirm that trenching will have no detrimental impact on water flow patterns and waterhole water retention timing.

Recommendation 8.13

That roads and pipeline surface water flow paths minimise erosion of all exposed surfaces and drains, and comply with design for fauna passage.

Recommendation 8.14

That all corridors be constructed to minimise the interference with wet season stream crossings and comply with relevant guidelines, such as the International Erosion Control Association Best Practice for Erosion and Sediment Control and the Australian Pipeline Industry Association Code of Environmental Practice 2009.

8.4.6 Other unacceptable impacts on wildlife

8.4.6.1 Wastewater or chemical spills

Any onshore shale gas industry requires at least the short term local storage of substantial volumes of wastewater of variable quality (Chapter 5), which may be toxic to animals. There are two ways wildlife can gain access to contaminated water:

- open wastewater storage ponds; and
- on-site or off-site spills.

In Chapter 7, the Panel has recommended that enclosed tanks be used to hold wastewater in preference to open ponds (***Recommendation 7.11***), which would prevent access by wildlife. The mitigation of chemical spills has also been dealt with in Chapter 7.

8.4.6.2 Noise and light

Any onshore shale gas industry involves short term increases in noise during site clearing, well drilling, and the construction of roads, pipelines and other infrastructure. It involves longer term increases in noise during production, particularly with pipeline compressor stations.[188] Chronic noise can influence wildlife in many ways,[189] with animals relying on vocal communication, such as birds, being especially affected.[190] Additionally, any onshore shale gas industry will involve sources of artificial light, which can have a range of effects on wildlife.[191]

Origin and Pangaea provided the Panel with information on how they would handle the risks to fauna from noise and light,[192] with Origin noting that there are no Government policies or other guidelines mandating noise limits for fauna in general.[193] As part of its EMP for Amungee, Origin conducted noise assessments considering the potential noise emissions, proximity to nearby sensitive features (habitat and landholders), and whether or not the relevant regulatory noise criteria was likely to be met. Where a sensitive ecological community was identified, a range of noise management measures were applied to reduce noise impacts to below acceptable levels. These included:

- the use of buffers to provide minimum distances away from sensitive features;
- the relocation of the noisy activity;
- the rescheduling of the noisy activity; and
- the selection of low noise emitting equipment or the use of noise attenuation devices.

Origin noted that there is little evidence that lighting from onshore shale gas facilities has an impact on fauna likely to be present in the Beetaloo Sub-basin.[194] Assessment of the potential impacts from facility lighting is undertaken as part of the EMP. Mitigation measures include:

- the design of facilities to use low impact lighting (including light selection, light orientation, and the use of motion sensors);
- locating major facilities away from potentially sensitive habitat areas; and
- unmanned infrastructure (such as lease pads) to have minimal to no lighting because it will not be frequented at night.

The Panel has assessed that the effects of noise and light will be very localised, potentially affecting a very small part of a development area, and therefore, would be unlikely to pose a significant risk to regional biodiversity values. Additionally, if it is assessed that there are sensitive species in the vicinity of any onshore shale gas operation, measures are available to mitigate any effects.

188 Peterson 2015.
189 Francis and Barber 2013.
190 Bayne et al. 2008; Francis et al. 2011.
191 Rich and Longcoren 2006; Stone et al. 2009; Perkin et al. 2011.
192 Origin submission 153, pp 100-101; Pangaea submission 220, pp 45-46.
193 Origin submission 153, pp 100-101.
194 Origin submission 153, p 101.

8.5 Landscape amenity

The Panel's other objective in assessing the land related risks of any onshore shale gas industry in the NT is to ensure that the perception of residents and tourists that the NT is a place of largely unspoiled landscapes is not diminished. Two aspects have been assessed:

- the risk of landscape transformation, whereby surface infrastructure becomes a highly visible and a dominant feature of the landscape due to the close spacing of well pads (as has sometimes been the experience with onshore gas developments overseas);[195] and
- the risk of very high volumes of heavy-vehicle traffic during the development phase, which can have a substantial impact on landscape amenity and identity with place, both within and beyond a development area.[196]

8.5.1 Unacceptable landscape transformations

The impacts of land transformation on landscape amenity are a function of, first, the location of any development in relation to scenic value and tourist visitation, and second, the scale and visibility of infrastructure within the development area. The Panel defines acceptable landscape change as a result of shale gas development as:

- no impact on the physical appearance of the NT's most scenic and highly visited outback landscapes; and
- minimal visibility of shale gas infrastructure from public roads in areas where development occurs.

The Panel recommends the exclusion of shale gas development in the NT from national parks or other conservation reserves, which contain many of the most scenic landscapes (see ***Chapter 14***). However, there are other landscapes of high scenic and amenity value in the NT that currently would not be excluded from shale gas development. For example, the vast areas of the internationally significant Greater McDonnell Ranges and Cleland Hills coincide with known prospective shale deposits but are not currently afforded any protection from development.[197]

Central Australian landscape.

195 Lock the Gate Alliance (NT), submission 56 (**Lock the Gate submission 56**), pp 8-17.
196 Lee 2013.
197 Harrison et al. 2009, p 2.

The Panel's assessment of the likelihood of unacceptable impacts on landscape amenity is 'medium', given experiences with onshore gas development elsewhere. The Panel's assessment of the consequences of such impacts is 'high', given the importance of the NT's unspoiled landscapes. Therefore, the overall assessment of risk is 'high'. The Panel has identified two sets of possible mitigation measures, namely, the protection of scenic landscapes from any onshore shale gas development, and minimising the visual impacts of any shale gas industry on landscape amenity.

The Panel considers that all NT landscapes with high landscape amenity value, not already protected in national parks or other conservation reserves, should be identified then considered as possible 'no go zones' for onshore shale gas development. The Panel recommends that, prior to the release of any further land for exploration, the Minister should consider, among other things, whether the land is of high scenic value.

To assess the visual impacts of any onshore shale gas development, the Panel has used the Beetaloo Sub-basin, and information provided by the three companies, Origin, Santos and Pangaea, as a case study. The Panel has constructed a possible scenario of three developments, each consisting of 40-50 well pads and taking up an area of around 400-500 km^2 as shown in **Figure 8.5**. On the basis of the information provided by the three gas companies, these development sites would be separated by around 60-80 km, and would be unlikely to be visible from the Stuart Highway, the main north-south tourist route in the NT. During the drilling and hydraulic fracturing phases, rigs used for these purposes would be located on each well pad (assuming eight to 10 wells per pad) for approximately one year, and depending upon the number of rigs deployed, they would be on the development site for at least 10 years. Since these rigs are 20-30 m high, they would be visible for some distance in the very flat Beetaloo landscape.

During the drilling and extraction phase, the Pangaea development would possibly be visible from Western Creek Road, the Origin development from the Carpentaria Highway (the main sealed road from the Stuart Highway to Borroloola, 26,000-33,000 vehicles used this highway in 2015[198]), and parts of the Santos development from the Carpentaria Highway. However, during the production phase, when the drill rigs are removed and the height of the remaining infrastructure is much less (approximately 2 m high), there will be limited visibility of any infrastructure from any major road.

The Panel's assessment is that the likelihood that the infrastructure associated with any shale gas development in the Beetaloo Sub-basin will be visible from public roads, particularly during the drilling and hydraulic fracturing stages, is 'medium'. However, the Panel finds it difficult to assess the consequences of this change to the amenity value for tourists or Territorians, because of their subjective nature.

The Panel heard community concerns regarding the potential for the landscape to be industrialised by any onshore shale gas industry.[199] The move to multi-well pads has significantly reduced the surface footprint of shale gas developments in the US,[200] and has the potential to also do so in the NT. As noted above (see Section 8.3.1), the development of any shale gas industry in the Beetaloo Sub-basin could result in around 150 well pads spread over three locations each being around 400-500 km^2 (20 km x 25 km) in area. These assume a distance between well pads of approximately 2 km.

The Panel received a number of submissions expressing concern that any onshore shale gas industry would result in over industrialisation of the NT landscape.[201] One way to address this is to mandate a minimum spacing between well pads. Origin argued to the Panel that, *"imposing pad spacing is inefficient and un-optimized … as the total surface area footprint per area of subsurface developed… will increase."* [202]

The Panel considers 2 km to be the minimum distance between well pads likely to be adopted by industry, given that it is expected that 3 km (or more) long laterals will be drilled and fractured. It is the Panel's expectation that the gas companies will seek to increase the distance between well pads beyond 2 km. Industry is concerned that if a minimum well spacing is mandated, it could lead to both suboptimal recovery of gas reserves and to a larger surface footprint because of a

198 DoT 2015.
199 Lock the Gate submission 56, pp 8 - 19; ALEC submission 88, p 14.
200 Manda et al. 2014.
201 Lock the Gate submission 56, pp 8-19; ALEC submission 88, p 14.
202 Origin submission 433, p 50.

need for longer roads and pipelines.[203] However, industry concerns about potential limitations of access to gas reserves have to be balanced against the need to avoid unacceptable landscape industrialisation.

Perceptions of landscape amenity are highly subjective. There is no objective standard for well spacing that prevents perceptions of landscape industrialisation due to onshore shale gas development. In other jurisdictions, minimum spacing between well pads is sometimes included in codes of practice,[204] and occasionally regulation,[205] but generally not for the purpose of protecting landscape amenity. Given that the three gas companies with exploration permits in the Beetaloo Sub-basin have indicated that they would seek to develop well pads with a spacing of around 2 km,[206] it is the Panel's opinion that a minimum distance of 2 km between well pads should therefore be mandated.

The second method by which the impacts of any onshore shale gas industry on landscape amenity can be ameliorated is to reduce the visibility of infrastructure within development areas[207] by ensuring that well pads are established away from major public roads. The gas companies should locate their well pads so that they are not seen from major public roads, particularly during drilling and extraction.

Recommendation 8.15

That to minimise the impact of any onshore shale gas industry on landscape amenity, gas companies must demonstrate that they have minimised the surface footprint of development to ALARP, including that:

- ***well pads are spaced a minimum of 2 km apart; and***
- ***the infrastructure within any development areas is not visible from major public roads.***

8.5.2 Unacceptable increase in heavy-vehicle traffic

The scientific literature contains a range of estimates of heavy-vehicle requirements for transporting equipment and supplies during any onshore shale gas development, including up to 2,000 truck trips for a high volume hydraulic fracturing event,[208] more than 3,300 one-way truck trips for the development of each horizontal well,[209] and between 4,300 and 6,600 total truck visits to service a six-well pad.[210] Despite some inconsistencies in the above estimates, it is clear that any onshore shale gas development requires high volumes of heavy-vehicle traffic. This can have a significant impact on landscape amenity and place identity both within, and beyond, a development area,[211] including for residents of towns located on major highways and tourists travelling along them.[212] Impacts can be through traffic congestion on roads or through the visibility of large vehicles creating perceptions of landscape industrialisation.

The Panel has obtained estimates of the current annual traffic volumes along the Stuart and Carpentaria Highways, the two major roads in the Beetaloo Sub-basin.[213] In 2015, the estimated annual traffic volumes were:

- Stuart Highway near Daly Waters: 151,000-164,000 vehicles; and
- Carpentaria Highway near Daly Waters: 26,000-33,000 vehicles.

It is likely that a considerable number of these vehicle movements along the Stuart Highway are tourists.

The Panel is unable to make an assessment of this risk because of a lack of relevant information on the estimated increase in heavy-vehicle traffic that will result from any shale gas development in the Beetaloo Sub-basin, or elsewhere in the NT. Information is needed on the estimated

203 Santos submission 420, pp 7-8; DPIR submission 424, p 9; Origin submission 433, p 50.
204 Queensland DNRM 2017a, p 9.
205 Texas Railroad Commission 1976, p 91.
206 Origin submission 153, p 40; Santos submission 168, pp 41-42; Pangaea submission 427, p 10.
207 See, for example, Origin submission 433, p 55.
208 Hayes et al. 2015; Goldstein et al. 2014.
209 Bureau of Oil and Gas Regulation 2011.
210 Broderick et al. 2011.
211 Lee 2013.
212 Alice Springs Town Council submission 235, p 2.
213 DoT 2015.

increase in volume at various time of the year, types of vehicles (heavy vehicles compared with other vehicles), supply sources, and the cumulative effects of multiple development areas. The Panel recognises that the gas companies will be required to address traffic risks as part of their EMPs,[214] but these assessments do not consider the cumulative impacts of multiple developments.

Increased heavy-vehicle traffic along the Stuart and Carpentaria Highways will continue over an extended period of time. Without more information on the potential increase in heavy-vehicle traffic, it is not possible for the Panel to assess the consequences to residents and tourists, except to note that the greatest impacts are likely to occur during the dry season when most tourists will be travelling and when any onshore shale gas activity is likely to be increased.

The Panel has identified three measures that could assist in minimising the risks and inconvenience that will be caused by an increase in heavy-vehicle traffic, namely:

- upgrading major highways by constructing overtaking lanes and dual carriageways;
- requiring heavy vehicles to travel at night (although it should be noted that road kill (vehicle strike) most commonly occurs during the night[215]), early morning, or late afternoon;[216] and
- the use of rail to deliver supplies to the region. Pangaea has suggested that the existing Adelaide to Darwin railway line could be used,[217] but there has been no analysis of the feasibility of this suggestion, or the extent to which it would reduce road movements.

Recommendation 8.16

That the Government assess the impact that all heavy-vehicle traffic associated with any onshore shale gas industry will have on the NT's transport system and develops a management plan to mitigate such impacts. Consideration must be given to:

- ***forecast traffic volume and roads used;***
- ***the feasibility of using the existing Adelaide - Darwin railway line to reduce heavy-vehicle road use; and***
- ***road upgrades.***

8.6 The need for the strategic development of any onshore shale gas industry

The Panel heard many concerns from the community suggesting that the development of any onshore shale gas industry in the NT must not, if the moratorium is lifted by the Government, be permitted to be rolled out in the ad hoc and inadequately regulated manner as the CSG projects in Queensland.[218] The Panel agrees. Any onshore shale gas development in the NT must occur in a strategic and coordinated manner. In particular, there are many areas where a cooperative and collaborative approach to infrastructure construction would be highly advantageous. These include road and pipeline networks, water treatment facilities, and gas processing facilities.

8.7 Conclusion

The Panel recognises that the NT is renowned for its spectacular landscapes and that these landscapes have exceptional terrestrial biodiversity and ecosystem value. The Panel has considered the risks relating to the potential loss of terrestrial biodiversity, ecosystem function and landscape amenity if any onshore shale gas development proceeds in the NT. It has identified a range of measures for mitigating these risks, including designating areas of particularly high conservation or scenic value as 'no go zones', developing and implementing effective plans for weed and fire management, limiting vegetation loss and the impacts of roads and pipelines, reducing the visibility of infrastructure in development areas, and managing heavy-vehicle traffic. It is the Panel's conclusion that these mitigation measures can, if implemented and enforced, reduce the risks to acceptable levels.

214 Petroleum Environment Regulations Guide, p 10; Pangaea submission 427, p 17; Origin submission 433, p 63.
215 Dique et al. 2003; Magnus et al. 2004, cited in Eco Logical 2012.
216 Hubbard et al. 2000, cited in Eco Logical 2012.
217 Pangaea submission 427, p 17; Origin submission 433, p 64.
218 Lock the Gate submission 171, p 3.